



Summary Report: Assessment and diagnosis of district heating networks

**Experiences from different European
demonstration cases**

The content of this document was prepared under the responsibility of different project partners and their related demonstration case(s). Below you find the responsible authors and the demonstration case(s) they have been working with.

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The Upgrade DH project

The overall objective of the Upgrade DH project is to improve the performance of district heating (DH) networks in Europe by supporting selected demonstration cases for upgrading, which can be replicated in Europe.

The Upgrade DH project supports the upgrading and retrofitting process of DH systems in different climate regions of Europe, covering various countries: Bosnia-Herzegovina, Denmark, Croatia, Germany, Italy, Lithuania, Poland, and The Netherlands. In each of the target countries (Figure 1), the upgrading process will be initiated at concrete DH systems of the so-called Upgrade DH demonstration cases (demo cases). The gained knowledge and experiences will be further replicated in other European countries and DH systems (replication cases) in order to leverage the impact.

Core activities of the Upgrade DH project include the collection of the best upgrading measures and tools, the support of the upgrading process for selected district heating networks, the organisation of capacity building measures about DH upgrading, financing and business models, as well as the development of national and regional action plans.

In addition, an image raising campaign for modern DH networks will be carried out in the Upgrade DH project. The outcome will be the initiation of district heating upgrading process in the above-mentioned target countries and beyond.

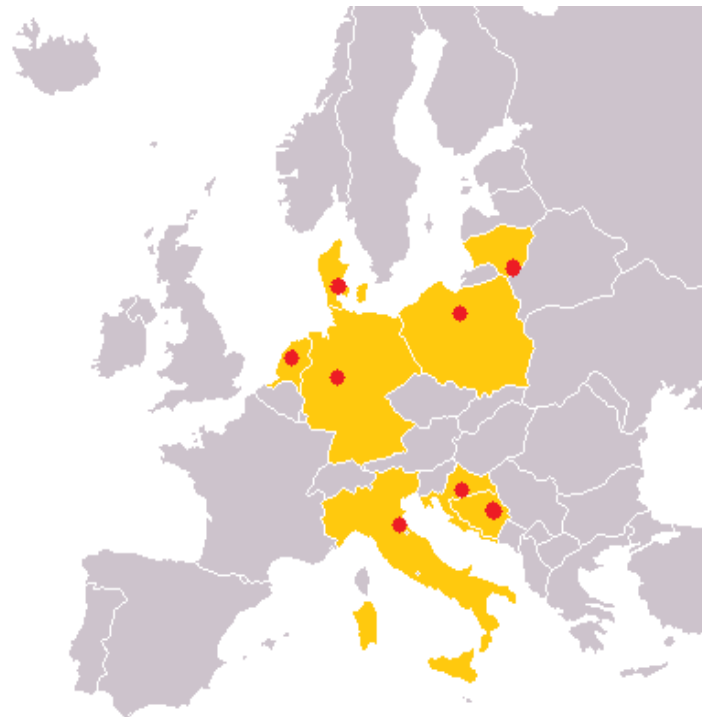


Figure 1: Upgrade DH target countries and demo cases

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1 Introduction

This document shares the experiences that were made within the assessment and diagnosis phase in the EU H2020 Project Upgrade DH. The 8 demo cases created local working groups, applied global assessment templates and conducted interviews within the companies or related stakeholders. Alongside, different tools were applied in order to find suitable measures that shall be further analysed and potentially implemented in the continuing possess of the project. Additionally, project internal webinars were held to share each other's expertise in different areas. These expert coaching webinars have also had relevant impact on the decision-making and is therefore recommended for other upgrading processes.

The focus of this document is on the success of the method and pathway that has been taken within the first steps of increasing the efficiency of district heating networks. Each demonstration case is shortly introduced and the local experiences during the analysis phase of the DH systems is elaborated.

Technical and organizational conditions are varying between the demonstration cases. These variations have also influenced the workflow of the working teams as the different chapters show.

2 Summaries of demonstration cases

This chapter introduces all eight demonstration cases. Each case has specific characteristics which requires different measures and ways of approaching the upgrading process.

2.1 Bologna-Ferrara

The systems located in the Bologna-Ferrara area below reported are operated by Hera, the regional multi-utility, managing the supply chain from generation up to the end users.

2.1.1 Bologna Ecocity DH Network

The Ecocity DH Network is located in north-central Italy, precisely in Bologna (region Emilia-Romagna) and is interesting due to its heat generation mix and use of storage system. The network extends for 7.4 km and it has 54 users' substations. The energy mix contains two separate 1.85 MWeI CHP units (gas-powered endothermic engines), a heat storage unit and some gas boilers. Identified improvement measures are: advanced remote monitoring system, heat generation optimization, optimization of energy dispatching.

The system is constituted by various production sites:

- "Ecocity plant": Production of hot water at 90°C through 2 cogenerators and 4 boilers. Total installed power 33.784 MW;
- "CT3_ZA plant": Thermal integration / rescue station consisting of 3 hot water boilers
- "CT5_ZA thermal power plant": Thermal plant at the service of the Sport Palace in Casalecchio di Reno (near Bologna), consisting of 2 hot water boilers for the production of hot water at 90 ° "Boosting unit (relaunch) from TLR Ecocity network at 90°C to CT1_ZA": pumping station for relaunching the Ecocity district heating network, serving the residential sector Z1_A, consisting of 2 pumps for winter service controlled by an inverter.

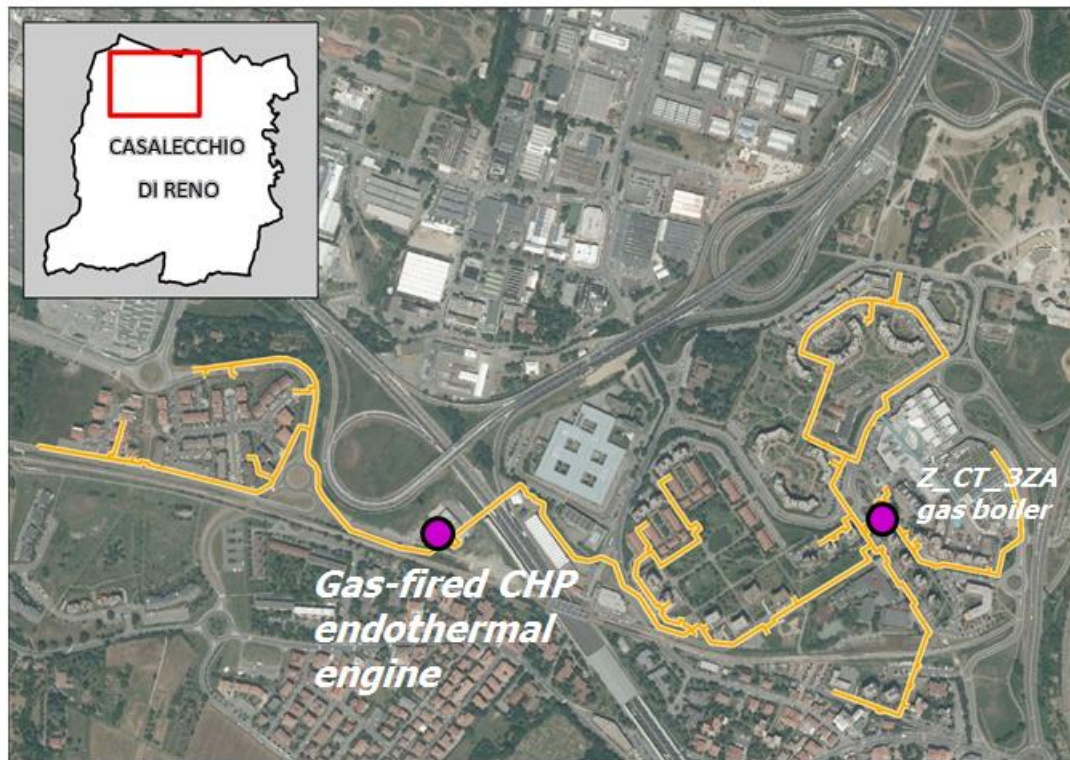


Figure 2: DH network Bologna Ecocity

2.1.2 Bologna Berti-Pichat DH Network

The Berti-Pichat DH Network is located in north-central Italy, precisely in Bologna (region Emilia-Romagna), representing some significant challenges since it comprises 2 networks operating at different temperatures (120°C and 90°C) and chill production. The network extends for 6 km as of 2014 (Hot Water Network); 0.77 km as of 2014 (Cold Water Network). There are 47 users' substations as of 2014. Energy mix is as follows: 2 separate 2.4 MWe. CHP (gas-powered endothermic engines), some gas boilers, absorption and compression chillers, heat exchanger between 120°C and 90°C heat network. Improvement measures that need to be further analysed are: advanced remote monitoring system, heat generation optimization, optimization of energy dispatching, interconnection with the equipments of San Giacomo power station.

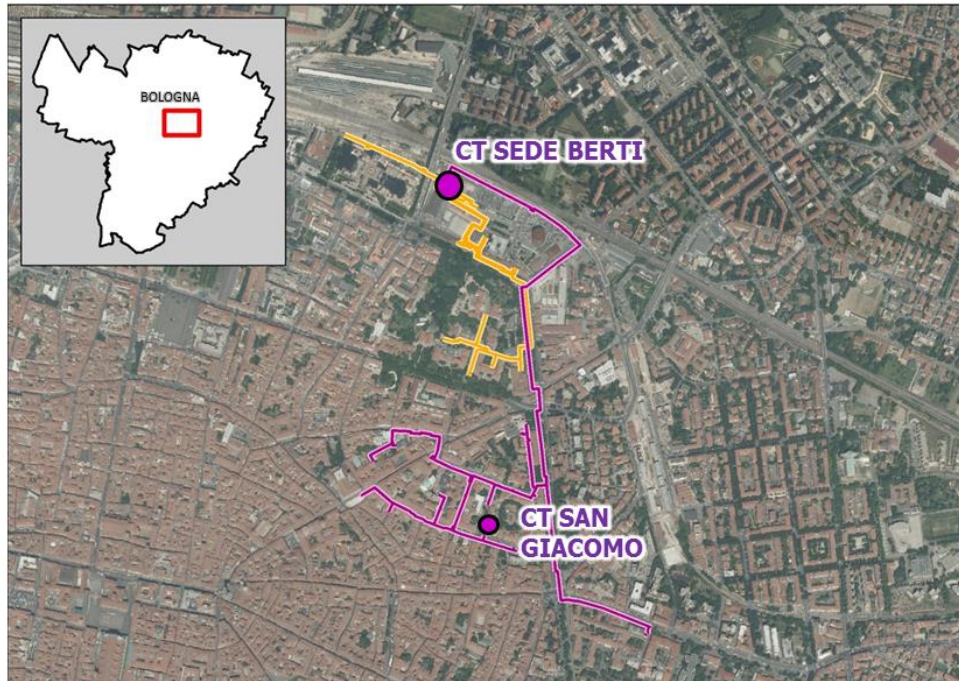


Figure 3: DH network Bologna Berti-Pichat

2.1.3 Bologna Barca DH Network

The Barca DH Network is located in north-central Italy, precisely in Bologna (region Emilia-Romagna). The network extends for 15 km and there are 120 users' substations. Energy mix contains 2 separate 3.9 MWel CHP (Gas Turbine) and 2 gas boilers. The system presents some challenges in the management of turbine cogeneration with tight technical constraints. Improvement measures are: advanced remote monitoring system, heat generation optimization, optimization of energy dispatching.

The current system is the result of the revamp of the old CHP plant (active from 1995 to 2015), next to which a new thermal plant (Acer-Barca) has been initiated. The latter is not to be considered as an additional production pole, since it has the purpose of furtherly raising the return temperature of the primary grid when needed. Moreover, in case of particular high demand (or emergency) two supplementary thermal plants (Ex Riva-Calzoni and Beccaccino) are available. The heat demand is for both space heating and hot water preparation.

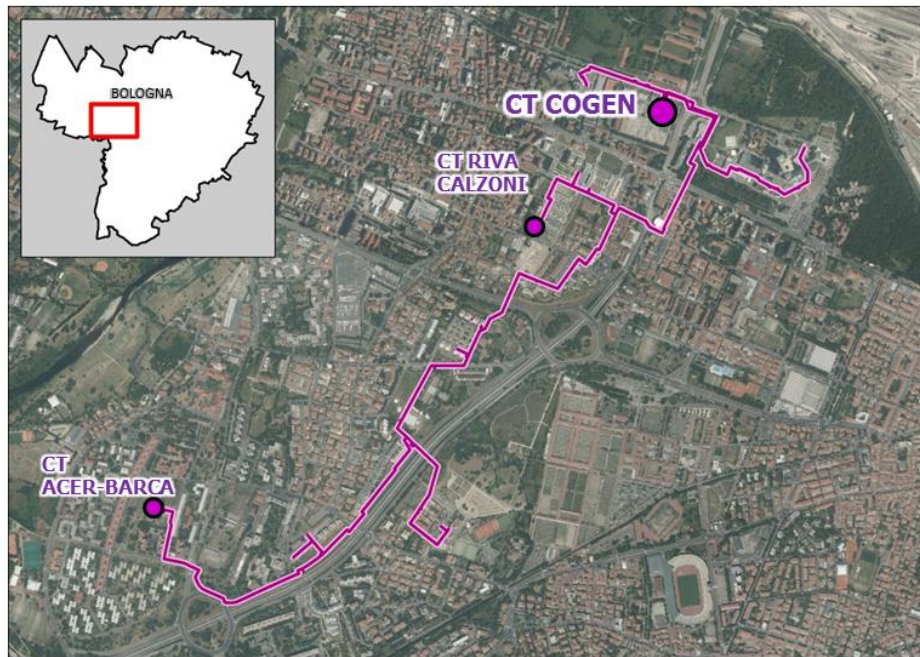


Figure 4: DH network Bologna Barca

2.1.4 Ferrara

The district heating system of the municipality of Ferrara supplies heat for space heating and domestic hot water in a rather large area of the city, located in north-central Italy (region Emilia-Romagna). The network is the result of 28 years of expansion since its start in 1990 and reaches a total route length of 80 km, connecting more than 600 substations and an overall volume of residential, public and commercial buildings of 5.75 million m³.

The supply side and demand side are separated by a two-tank storage system and the grid is fed by a main generation plant located in the north-west of Ferrara at a distance of 7 km from the city centre, supplying pressurized water at approximately 90°C and with return temperatures around 55÷60°C.

The main generation plant consists in a waste-to-energy CHP plant (WTE), a geothermal energy plant (GEO) and a set of seven gas-fuelled boilers (fire-tube type).

The grate-fired waste boilers can accept waste with a LHV from 1,800 kcal/kg (7.5 MJ/kg) to 4,000 kcal/kg (16.7 MJ/kg) and a throughput from 5.0 to 12.0 t/h of waste, while the thermal production ranges from 16.7 MWt to 27.9 MWt, providing a high degree of flexibility for the system management. Furthermore, the heat production may rise up to 30.7 MWt (i.e. 110% of the nominal load), yet for limited stretches (max a couple of hours).

The geothermal plant feeds from two production wells reaching a depth of 1,000 m, producing pressurized hot water at 102°C (from a maximum of 400 m³/h in the winter to a minimum 200 m³/h in the summer), which is sent to a heat exchanger, made of three plate heat exchangers in titanium, where the heat transfer (ranging from 5 and 14 MWt) to the network occurs. The cooled-down geothermal fluid is then reinjected in a single injection well.

The gas boilers serve mostly as a reserve, when the heat demand may not be covered with only WTE and GEO. The total installed boiler capacity is 84 MWt, and it is sufficient to satisfy the entire load in case of failure of the other production units.

A thermal storage is also present, so that the non-boiler units may be utilized also in low-load instances, both reducing fossil fuel consumption and allowing a boosted electric production from the CHP plant when prices are high.

The geothermal facility is used to supply the baseload (35% of heat production in 2017), the WTE plant the intermediate loads (52%) and the peak boilers are required for less than two months a year (11%).

Improvement measures that can be further analysed are as follows: advanced remote monitoring system, heat generation mix optimization, heat capacity saturation, pressure optimization based on proprietary methodology and algorithms, optimization of energy dispatching.

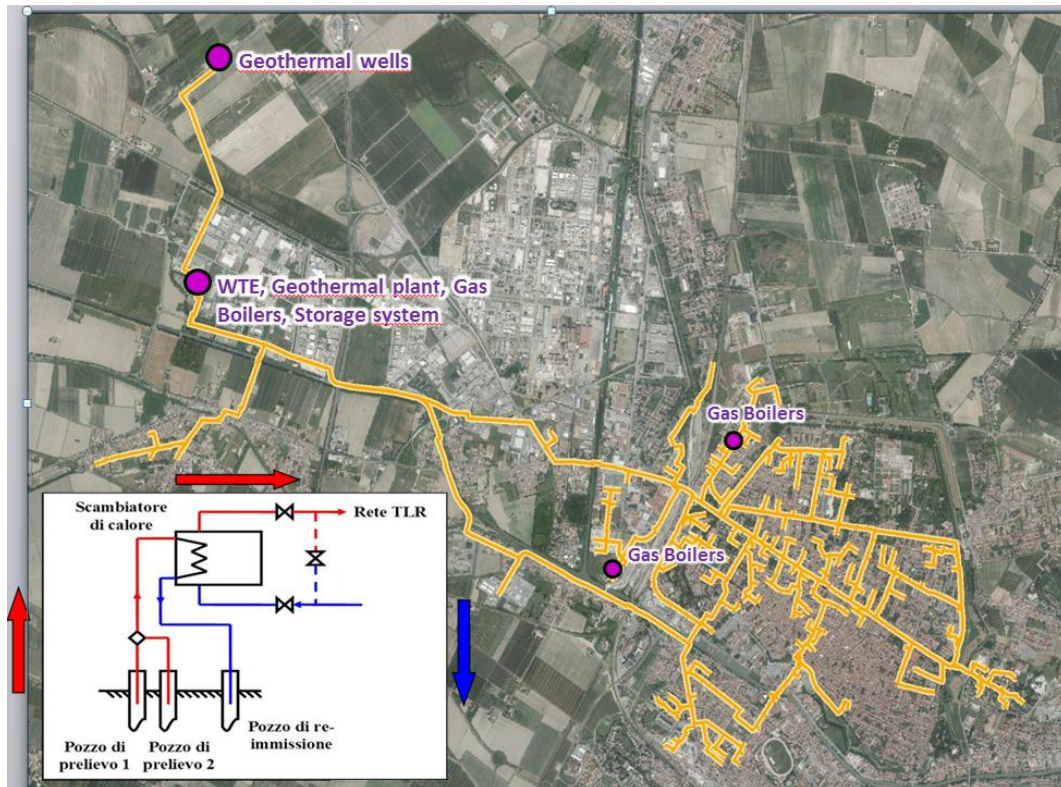


Figure 5: DH network Ferrara

2.2 Grudziadz

Grudziadz is situated in the Kuyavian-Pomeranian Voivodeship. The city of Grudziadz is supplied from the municipal heating system, operated by OPEC-SYSTEM Sp. z o.o. The subject of OPEC-SYSTEM Sp. z o.o. activity is the provision of heat supply services to municipal, residential and business units by means of heat transmission and distribution using a municipal heating network for heating, ventilation, technology and hot tap water preparation. The amount of heat purchased from the supplier in 2016 was 245,340 MWh. OPEC-SYSTEM municipal heating network, due to the city's longitudinal shape, has been divided into two networks: north and south. Both networks are supplied from a common source of Łąkowa CHP located in the central part of Grudziadz.

The technical parameters of the district heating system are (heating season 2016/2017):

- Temperature: 114/60°C (south network) and 108/60°C (north network), outside the heating season- 68°C,
- The maximum daily average mass flow: during heating season: 1688 t/h, outside the heating season: 292 t/h
- Maximum pipe diameter: DN600,
- The total length of the heating network is 98.9 km of which 44.9 km (45%) are pre-insulated pipes.
- At total 667 substations are connected to the network of which 498 are individual and 95 are group substations.

The heating system is regulated in a quantitative and qualitative manner. Depending on the outside temperature, the inlet temperatures of the heating system are adjusted. The basis for

adjustment is the temperature table. OPEC-SYSTEM is not the owner of the production plant. Łąkowa CHP, the production plant is owned by OPEC-INEKO Sp. z o.o. It is an energy producing source in the form of hot water, technological steam and electricity in a highly efficient cogeneration. The technological steam is produced for the needs of Schumacher Packaging Zakład Grudziądz Sp. z o.o. and OPEC-BIO Sp. z o.o. The electricity produced is used first of all for own needs, whereas the surplus of production is sold to Schumacher Packaging and trading companies.

The Łąkowa CHP has a total installed thermal power of 156.8 MW and 18 MW of electrical power. The installation includes:

- Water boiler type WR-10 (K7) – 11.6 MW of thermal power, connected to a steel chimney with a height of 40 m
- Three steam boilers type OR-32 (K1, K2, K3) and two water boilers type WR-25 (K4, K5) - 145.2 MW of thermal power, connected to a common concrete chimney with a height of 82 m
- Three turbines (TUP 6, TP 6, TUK 6) – 18 MW of electrical power in total.

Boilers K1 and K3 can burn either biomass or coal. At the same time, only one type of fuel is burned in a given boiler. K2, K4, K5 and K7 boilers are coal fired only boilers. All boilers are grate-fired boilers burning pulverized coal assortment.

In order to improve the network efficiency, network's temperature and pressure should be dynamically optimized. Currently approximately 50% of inhabitants use heat from the DH network while the air quality is concerned as a main challenge. Therefore, the main improvement is identified to be the intensification of activities related to substitution of local boilers with a district heating network. Moreover, around 10% of connected consumers still produce domestic hot tap water with local gas boilers.

Due to the varying heat demand by the largest industrial customer, the use of a heat storage unit should be considered. The heat storage would allow avoiding the network overheat caused by intensified heat consumption by the industry.

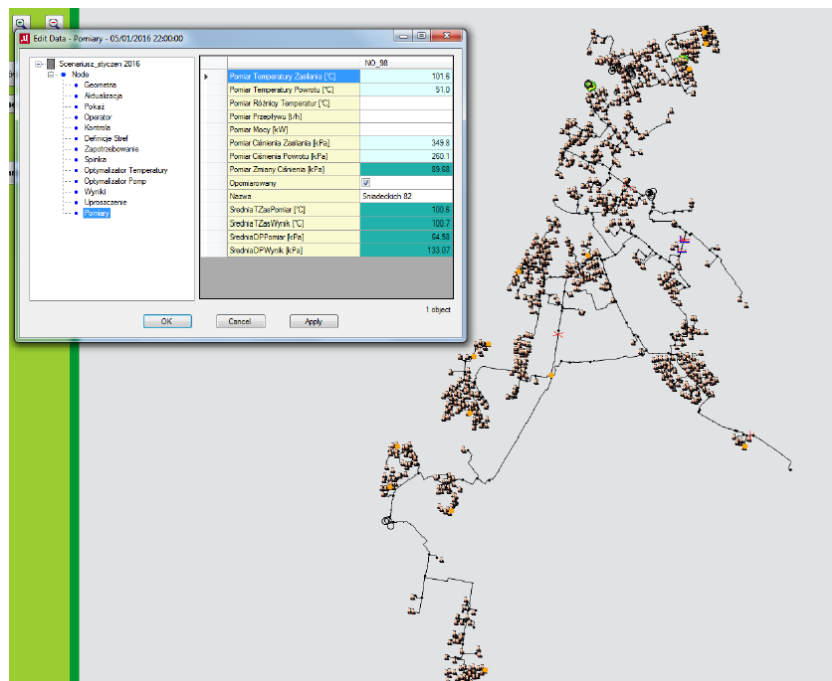


Figure 6: The main DH grid of Grudziądz

2.3 Marburg

The city of Marburg is located in the middle of the federal state of Hessen between Frankfurt and Kassel on the river of Lahn. The located county government is responsible for approximately 240,000 citizens and 72,000 thereof are inhabitants of the city itself.

One of the biggest heat consumers of the district heating network of the municipal utility Marburg is the Philipps-University Marburg. Founded in 1527 as the first protestant university in the world, with currently 25,000 students, it became an important factor for business, scientific and social life in the region. In May 2016 the state sold the 8 km district heating grid to the municipal utility Marburg. The contract also foresees that the network will be completely renewed for reasons of energy efficiency. The ambitious goal is to increase the overall efficiency with the benefit of decreasing costs and CO₂ emissions. Besides some remediation measures the city is interested to lower the supply and return temperature level and searching for retrofitting possibilities for inefficient heat exchangers, substations and coupled network parts. With the political claim to reach a CO₂ neutral country, the administration of the municipal utility Marburg needs to check numerous options and get expert advice to develop the most efficient solution.

2.4 Middelfart

The city Middelfart is located on Funen in the South-Region of Denmark, with around 15,246 inhabitants. The Middelfart District Heating System is divided into the two areas Hessgade and Fynsgade, which are organizationally in charge of both Middelfart District Heating Area, but also Nørre Åby District Heating Area. Middelfart DH does not supply Nørre Åby, since they have their own local energy system, meaning Middelfart DH only supplies the city of Middelfart.

The District Heating system utilizes industrial excess heat from TVIS as their main heat source, but they have a reserve capacity of 48 MW, that utilizes natural gas or fuel oil. The spare capacity is located on their main central facility (Hessgade 21B), and on their second central facility located on Fynsvej. From the main central facility on Hessgade to Fynsvej, a transmission pipe transports the excess heat from TVIS.

The average MWh that are supplied by the DH network was in 2017 around 122,086 MWh. Out of 122,086 MWh, the heat production on the natural gas boilers were 28,596 MWh, equal to 23% of the total heat production, and 94,491 MWh, equal to 77% of the total heat production, came from the industrial excess heat.

The temperatures in the network varies throughout the year, but in average, the supply temperature is 65°C and return temperature is 40°C. The district heating network's length is in total 148 km, including 75 km main pipelines and 73 km service pipes. The network consists of around 5,192 smart meters (substations) that provide information about the consumers heat demand. To optimize the current energy system, they can utilize the Termis Flow Temperature Optimization (FTO), which optimizes the supply temperature at the heat plants or the TERMIS Return Temperature Optimization (RTO) model, which can give information about lowering the return temperature at specific consumers through Smart Meters, which are already installed in Middelfart DH. The heat loss in the network is around 18%, which is a challenge for the district heating system, because it illustrates inefficiency. Therefore, lowering the heat loss must have a high priority, especially when expanding the distribution area and connecting more households to the network. These two types of software can be used to lowering the temperatures, which are key to staying competitive with e.g. individual solutions. A more long-term challenge for the DH systems in Denmark is that The Danish Government wants to be independent of fossil fuels in the energy production in 2050, meaning the utilization of natural gas must come to an end, which can cause a problem for many DH systems that utilize it as spare capacity.



Figure 7: Middelfart is interconnected 3 other cities with heat transmission lines from power plant and industries in the area

2.5 Purmerend

The city of Purmerend is located in a small province in the North-side of the Netherlands close to Amsterdam, with around 80,000 inhabitants. The DH system company, in charge of the heat production, is Stadsverwarming Purmerend (SVP) and around 75% of the buildings in the city are connected to the DH network of Purmerend. The length of the DH network is around 600 km and the heat production comes from three production plants. One biomass-fired production unit that provides 80% of the heat production and two gas fired CHP plants mainly used as spare/reserve capacity.

Due to many dikes and channels in Purmerend, the network is constructed using a special strategy. The main network, which can almost be regarded as a transmission system, delivers heat to a number of substations. These substations are typically located in an area that is fenced in by dikes. A substation supplies typically 200 to 500 customers. Another specialty is the supply of district heating to houseboats.

The capacity of the biomass-plant is 44 MW_{th} and it uses around 100,000 tons of biomass annually whereas their natural gas plants have a capacity of 79 MW and 22 MW. The heat demand and production from SVP varies during the year, because in the winter period, the heat is used for space heating and hot water whereas during summer it is only used for hot water. The peak demand can then vary from 150-20 MW depending on the outdoor temperature. The supply temperature in the network is in average 94 °C while the return temperature is 50°C. The total amount of substations in the network is 25,729 and the total amount of heat supplied by the DH is 345,058 MWh whereas the annual consumption is around 260,000 MWh. The maximum peak load was 131 MW in 2016.

The main challenges are the varying peak loads that can occur, which is leading to a lot of spare capacity. Another challenge is the high temperature regimes on both the supply and return temperature, leading to a high heat loss percentage in the network. To optimize the DH network, several renovations in the district heating grid have been conducted by replacing old pipes with new modern pre-isolated pipelines. This has led to reducing heat losses with 10%, water supply with 50% and unplanned service down by 84%. There are still more ways to improve the efficiency, because the temperature regime is high, so it can be lowered through creating a TERMIS Master model with a "Flow temperature optimization model" (FTO). The FTO model can calculate the minimum inlet temperature in the network while ensuring that the consumers have at least their minimum supply temperature secured. The TERMIS return

temperature model can optimize the consumers cooling of the return water, by identifying consumers with an insufficient cooling of the return water, enabling the DH company to take action through e.g. incentives. Purmerend is however, an efficient DH in the Netherlands, utilizing local CO₂ neutral resources in the production with a broad network and many costumers connected.

Purmerend (SVP) is considering the construction of a new biomass plant in the near future.



Figure 8: Biomass fired heating plant at Purmerend

2.6 Salcininkai

Salcininkai region is located in the south-eastern part of the country, at the border with Belarus. The total area of Salcininkai region is 1,419.4 km². According to the data received in 2018 there are 428 small and average companies in Salcininkai region. Salcininkai city is located 45 km from Vilnius, capital of Lithuania. The city has around 7,000 inhabitants.

Salcininku silumos tinklai, Ltd. is founded in 2000 and is 100% owned by Regional Municipality. The company involves more than 70 employees. "Salcininku silumos tinklai" (SSTINKLAI) produces, distributes heat to consumers. In addition, the company is responsible for the supervision of internal heating systems and substations in the buildings. The company operate 14 boiler houses in Šalčininkai country in which it produce and distribute heat to residents and institutions in 10 different locations (Šalčininkai, Eišiškės, Jašiūnai, Dieveniškės, B.Vokė, Šalčininkėliai, Čiužiakampiai, Butrimonys, Poškonys and Dainava). The total installed heating capacity is 48 MW. Heat is supplied via 18.7 km long networks which are connected to 2,168 consumers, 96.8% of whom are residents. Main (largest) DH network is located in Šalčininkai city. All the pipes used in the Company's owned DH network are insulated and protected from the climate conditions in accordance with the procedure established by legal acts. Circulating water is also prepared and cleaned in accordance with the procedures established by the legal acts and corresponds to the established values. Therefore, there are no major corrosion problems on the inside nor the outside of the pipes, nevertheless, minor signs of corrosion are visible.

39.2 GWh of heat was generated in 2017. About 14.7% of heat was produced from natural gas, 78.1% - from biomass, 5.6% - from firewood and 1.6% - using liquid fuels.

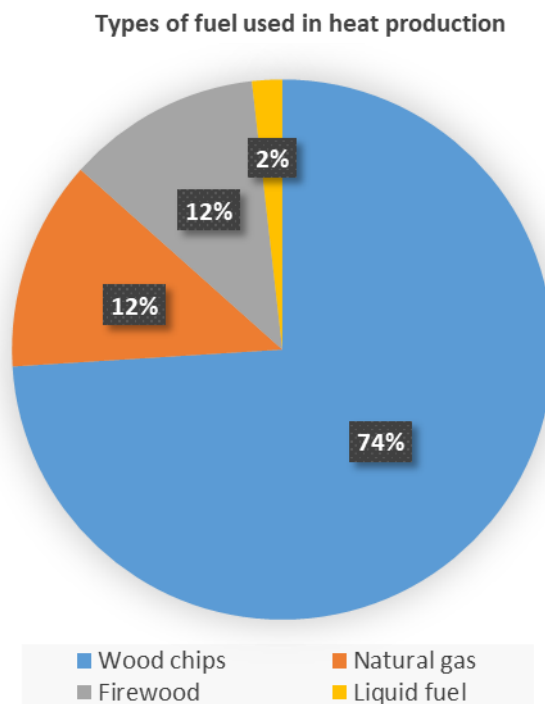


Figure 9: Fuel use in the DH network

2.7 Sisak

The target city of the Upgrade DH project in Croatia is the city of Sisak. It is a middle-sized city located in the Sisak – Moslavina County, southeast from the Croatian capital, Zagreb. The city is the administrative, cultural and historical center of the county, as well as one of Croatia's biggest river ports and industrial cities. Total number of inhabitants is 47,768, as stated in the 2011 population census. Out of this number, 33,322 inhabitants live in the urban settlement.



Figure 10: The location of the district heating production facility in the city of Sisak¹

Regarding the heat supply, parts of the city are covered by a district heating network, which is operated by HEP Toplinarstvo, a sister company of the Croatian largest energy utility company HEP Group. Overall, 4,308 consumers are connected to the DH grid, out of which 58 are industrial customers. Therefore, steam is also being distributed, mainly for industrial purposes. The distribution network is supplied by a cogeneration plant, with installed electric capacity

¹ Source: <http://www.hep.hr/proizvodnja/termoelektrane-1560/termoelektrane-toplane/te-to-sisak/1561>

420 MW_{el}. Accept from the cogeneration plant, a heat only boiler with the installed capacity of 120 MW_{th} supplies a separate DH network. The plan is to connect the two DH networks in near future. The overall heated area of households is 229,159 m², while for the other consumers (mostly industry) it is 3,800 m². Both heat production plants use natural gas as an energy source and are operated by HEP Toplinarstvo. Furthermore, a new biomass cogeneration plants has started its operation in 2017, with the installed capacity of 12 MW_{th}. The total heat delivered to customers in 2014 equaled to 66.77 GWh. One of the biggest problems of the district heating systems in whole Croatia, are the heat losses in the distribution network. Due to old and inefficient pipes, average heat losses of distribution networks operated by HEP Toplinarstvo are around 14%, while for steam systems they are significantly higher at 35 – 40%. However, the distribution network of Sisak DH is completely refurbished and therefore the losses are lower than 6%, with zero water losses. The overall distribution network length in Sisak is 30 km and the overall number of substations equals to 176.

2.8 Tuzla

Tuzla City is placed in the North-Eastern part of Bosnia and Herzegovina, and counts approx. 170,000 inhabitants. The district heating (DH) system Tuzla supplies thermal energy to approx. 80% of the residents of the City, whereby the number of connections enlarges each day.

Thermal energy for this system is produced in a cogeneration process (CHP) in Tuzla's coal-based power plant (TPP Tuzla) operated by the power utility JP Elektroprivreda BiH d.d. – Sarajevo (EPBiH). TPP Tuzla is the heat supplier to both, to Tuzla city (220 MW_{th}) and to Lukavac city (50 MW_{th}), whereby another nearby town of Živinice is planned to be supplied with the thermal power of 70 MW_{th} from this same heat source. The DH Tuzla network is operated by the distribution company Grijanje Tuzla, owned by Tuzla City.



Figure 11: Map of the DH network in Tuzla

The instantaneous power of DH Tuzla is 220 MW_{th}, with designed temperature regime 145/75°C at -17°C outdoor air temperature and steady fluid flow. The DH Tuzla system consists of 10 km of main pipeline (DN600-DN250), while about 170 km of heating network is ensuring that heat from the Tuzla TPP reaches the customers. There are around 1,030 heating substations. Big substations (195 – 1,200 kW) are supplying tall blocks of flats, others (60 - 190 kW) are supplying small and medium-sized buildings and finally a small type of substation (20 - 55 kW) is used for individual houses. There are 17 points on the remote control and

management system of district heating network together with 39 heating substations. The total heating area is 1,732,660 m² with 23,200 consumers (almost 90% of flats, other are 10% commercials).

It should be considered that the DH Tuzla system in this form is in exploitation for 27 years, and some parts of the heat network are aged over 35 years. In the past 10 years, a large number of old substations have been replaced by new modern ones, while distribution side pumps have been replaced by electronic pumps. It is recognized that the system could be more efficient and economical. To achieve a more efficient and sustainable DH Tuzla system, the following tasks are subject for further improving and upgrading: performing better designing of the reconstruction and expansion of the DH Tuzla system, upgrading the remote control and management, as well as introducing RES-based solutions into the DH Tuzla system.

3 Local working group experience

Partners from each demonstration case have listed their experience made during the creation of the working group as well as from the meetings in the following chapters. Some cases have experienced long term consultancy services from project partners, which has an impact on the way of approaching new upgrading measures and treating already decided measures.

3.1 Bologna - Ferrara

The working group in Ferrara involves a wide range of stakeholders, since DH in the city is particularly developed and connected to the social issue. The meetings seek to ensure wide participation of the local community, in line with the project's objectives.

The local stakeholder group in Ferrara has met once so far, with future follow-up meetings expected in the coming months. The group counts a strong presence from HERA, with resources from different sectors and group's companies: Hera s.p.a. (involved in the overall DH systems' management), Hera Trading (involved in interfacing with the electrical markets), HeraTech (involved in design and engineering activities). The common objective was to define common strategic guidelines for upgrading measures, as well as to discuss some practical issues characterizing the DH system. The industrial world was also represented, e.g. by OPTIT and its Energy team, with experience in the applications of analytics, optimization and digitalization to energy management, and by Enel Green Power, technical partner that has a lot of experience in the geothermal technologies. The academic world was well represented, with researchers from Bologna University and Ferrara University, together with professional associations, aiming to trace the evolution of the project in its possible impact on the DH system from a technological standpoint. Finally, the local administration, through the technical director and his collaborators in the geology and energy sector, has participated to reinforce its support to all activities that could make more efficient and accessible the district heating service for all current citizens, including the option to foster new potential connections, since DH represents a powerful strategy for an increasingly "greener" Ferrara.

The working group in Bologna involves, for the time being, more of a scientific/technical presence, since the most pressing issues and perspective upgrading opportunities in the local networks are mostly related to technical matters.

The local stakeholder group in Bologna has met once so far, with future follow-up meetings expected in the coming months. In the first meeting there has been a strong presence from HERA, with people from different sectors: Hera s.p.a. (involved in the overall DH systems' management) and HeraTech (involved in design and engineering activities). The common objective was to define some strategic guidelines for upgrading measures, as well as some practical issues characterizing the DH system. OPTIT and its Energy team has attended also, as an industrial partner, together with a professor of the University of Bologna, aiming to trace the evolution of the project in its possible impact on the DH system from a technological standpoint. Finally, an expert of heat pump technology participated, in order to offer its experience on the matter for potential application in Hera's demo cases.

All in all, the creation of such groups has been a very positive experience, since it created occasions to share every party's perspective on technical and non-technical issues. The dialogue stimulated interesting insights that may have impacts on the decision-making process regarding the DH systems' retrofitting strategies.

Furthermore, the strategy for setting up groups document (see: *Annex A*) suggested a structural framework from an organizational standpoint, defining some general guidelines for each phase of the working group's activities, provided that the activities leveraged on Hera's long-lasting experience in multi-stakeholder engagement, often liaising with administrative and institutional representatives, which proved to be a valuable asset while gathering and managing these activities.

3.2 Grudziadz

The potential upgrading measures have been identified by a working group that includes the OPEC-INEKO (Heat production) and OPEC-SYSTEM (Heat distribution and end use) and representatives of the consultant COWI.

The local group consists of five people covering the interests of the whole production and distribution system consisting of the following positions: DH senior specialist, DH Technical Director, Electrical power specialist, Laboratory Manager, Head of Electricity Department.

The working group meetings have been helpful to identify main contents of master planning.

3.3 Marburg

All communications and planning tasks are easier when there is only one contact person of the involved companies. In the case of Marburg the responsible engineer for heat planning and distribution is the main contact person. In this position, he has to deal with almost everyone involved in day-to-day business. That's why he knows both the operating staff who operate and maintain the networks, power plants and transfer stations etc. and also the people who care about acquisition, customer care, planning or corporate strategies. Depending on the planned agenda the necessary experts were invited to participate at the local working group (LWG) meetings. AGFW, the responsible Upgrade DH project partner, adjusted the expert team according to the LWG meeting agenda.

For the beginning of the constituent meeting it is important to have decision makers for the clarification of the boundary conditions and targets of the upcoming activities. Regardless which of the upgrading categories will be the main focus (managerial, economical, technical, organisational), it is necessary to understand the current situation of the DH system. Therefore, the first LWG meeting in Marburg contained a visit to the power plant, to discuss with the operating persons, who were also responsible for the distribution and usually know best the situation of the DH system.

With the structured questionnaire of Annex B, some key facts were collected before the second LWG meeting. Most values could be collected and exchanged without a physical meeting, the discussion on specific values and how to gather missing ones, led to detailed discussions and increased the understanding of the current situation. Due to the fact that SWMr are responsible for the whole supply chain of the DH system and the main contact person is involved in most of that, the meeting was quite efficient with a small group of people.

As every DH system is quite individual and many values of the Annex B questionnaire depend on the way of calculation, it is important to analyse the given answers and discuss open questions afterwards. Therefore, technical staff was involved again in the third meeting of the LWG.

The strategy of setting up a local working group is a good start to think of whom to involve at what time. Within the special situation that AGFW is a well-connected association, there were already some contacts that could be used as a starting point without starting from scratch. The "set up" of the LWG was also easy because the organisation of SWMr covers the whole supply chain in one company. In case of specific questions, the experts were involved in the LWG without difficulty. Starting with a general overview of the issues and targets is of course a good idea for the first meeting. For the ongoing activities the Annex B questionnaire proved to be a good and structured way to get in the discussions.

Even in Tuzla, where AGFW also supported the activities of the LWG, the physical meetings are most important to understand the real issues and ideas of the people in charge. There were much more details, discussions and exchange on technical issues during the meetings in Marburg or Tuzla than ever possible in the webinars. The activities of both LWG will continue and seems to be on a good way to become an effective process of upgrading.

3.4 Middelfart

COWI has the pleasure of being a house consultant for several years and has dialogue on a regular basis with the Director Jesper Skov and the operational staff. This means that the Upgrade DH initiative does not start from scratch. Therefore the proposed Upgrade initiatives must be seen as final elements in a long row of subprojects in a long-lasting relationship. The work in Middelfart has inspired a follower city Næstved to do same kind of analysis.

3.5 Purmerend

The potential upgrading measures have been identified by a working group that includes the Director, Technical Director and operational personnel of Stadverwarming Purmerend and representatives of the consultant COWI. This means that the Upgrade DH initiative is part of a long row of subprojects.

Changes in personnel can influence viewpoints. The interview tool has not made much difference. What gets things moving is to reach a common understanding of the challenges in the system and to use tool like Termis to clarify consequences of potential different changes.

3.6 Salcininkai

The Working Groups play a central role in the daily work. They are the primary forum through which partners collaborate with each other on substantive issues. The local workgroup meetings were always attended by all relevant actors, starting with representatives of the local authority, such as Head of Department of public utilities, Head of Department of Investments and planning, specialist of Department of constructions and architecture, ecologist and representatives of end users, such as Deputy Director of JSC „Tvarkyba” (administrator of apartment buildings) and eldership of Salcininkai.

Working groups meet once in few months to discuss the main issues. During work group meetings, the members presented problems and offered certain solutions.

Heat production:

Potential solar thermal implementation in a small system which can operate during summer months and replace main heating source in Salcininkai city. During the meeting participants discussed about the current demo case situation and solar district heating implementation challenges, such as scarce knowledge of the solutions' technical and economic parameters and high upfront costs. The local working group set the area that could be used for the collector field.

Heat distribution:

Actions are needed to accelerate the cost effective and energy efficient retrofitting existing inefficient district heating networks.

Heat use:

As necessary actions should consider interventions that are needed on the building side e.g. retrofitting and / or modifications of internal heat distribution systems and system and end user controls. The district heating supplier should also take into account the evolution of thermal demand in the future due to improving building energy performance standards and increased rate of building renovations.

All in all, the working groups had a positive impact for the upgrading measures, since it includes all relevant stakeholders. The strategy for setting up groups (Annex A) was a helpful guideline at the working group setting stage as it answered most of the emerging questions and revealed what outcomes should be expected.

3.7 Sisak

The formulation of the working group in the target city of Sisak started in October 2018, with the first meeting in the form of the phone call. A representative of the district heating production company HEP Proizvodnja participated in the first call and therefore presents a founding member of the working group. The main idea of the first meeting was to define the other potential stakeholders which would be beneficial for the working group. The outcome of the discussion was that in the first year, the members should be from the heat production and distribution side, since they have the most knowledge on the details of the system, covering production, distribution, as well as the end use of heat.

Therefore, in all the other meetings in the first year of the Upgrade DH project, a representative from HEP Proizvodnja and the representative from the distribution company HEP Toplinarstvo were present. Members from HEP Proizvodnja include an engineer responsible for the maintenance in the production process, as well as the director of the company in order to have a broader overview of both technical and non-technical details of the current system. From the heat distribution company, only the director of the company participated in the meetings so far. Having high ranking representatives of the production and distribution company showed rather beneficial for the process in general since the upgrading measures could be prioritized and defined in significantly less time. The main interests both from HEP Proizvodnja and HEP Toplinarstvo in participating in the working groups are focused on improving the system from the production side, for which the UpgradeDH project has been identified as the perfect facilitator.

So far, the working group has met three times, not taking into account the first phone call. It has been decided that the optimal frequency of the meetings would be 2-3 months, therefore the meetings have been held on 18th October 2018, 5th December 2018 and 26th March 2019. The meetings have continuously improved from the initial one, giving a more detailed picture of the current state of the system, its best practices as well as its problems. This provided a great insight into the system, as well as its historical development. It has been shown that the heat distribution is rather efficient in Sisak, since the pipeline network has been completely refurbished, leading to low energy and water losses. Furthermore, the substations at the end users have also been refurbished and efforts are being made to lower the users' temperatures, and therefore the system temperatures as well.

This has led to the definition of the focus of the improvement analysis, concluding that the heat generation side currently has the most issues with the need of attention. Therefore, three main upgrading measures have been defined for the heat production of the district heating system of Sisak, i.e. integration of solar thermal flat plate collectors in the heat production mix; integration of the thermal storage system at the heat production side; and waste heat utilization from the condensate for the technological purposes in the system.

The results from the tools used for the analysis have also been discussed during the meetings. The GIS heat demand map, developed by UNIZAG FSB has shown the potentials for the district heating extension in Sisak, pointing out that the highest heat demand densities in the city are at the old town, i.e. the city centre which is currently not connected to district heating. This corresponds with the plans from the distribution company, which started using TERMIS recently for the grid expansion analysis. Another area with higher heat demand densities are the neighbourhoods of Budaševo and Topolovac, which are located much closer to the heat production plant, compared to the city centre. Therefore, expanding the connection to cover the demands in these parts of the city can also be considered in the future.

The working group will expand in the second year of the project and will try to include the local authorities, as well as the representatives of the local academia in order to discuss further possibilities of efficiency increase in the heating sector of the city of Sisak. It would be beneficial to also include the end users of heat in the discussion, however this is expected to be harder since there are no official representatives of the heat consumers in the city. Creating such a working group at the beginning of the upgrading process is recommended in order to facilitate the process and have all the important stakeholders' included from the beginning. The Strategy

for setting up groups proved to be very helpful at the beginning of the working group formation, providing recommended steps for the process.

3.8 Tuzla

From the very beginning, the aim was to include all relevant stakeholders which represent the DH system in Tuzla. Prior to the official initial meeting of the local working group (LWG), a pre-kick meeting was held, attended by the main actors in the system: heat energy production utility - EPBiH (TPP) and heat distribution utility 'Centralno grijanje Tuzla' – DH Tuzla. At that meeting, besides the objectives and importance of the Upgrade DH project for both sides, all other potential members of the working group were discussed. It was concluded that besides the main actors (EPBiH and DH Tuzla), the local working group should be expanded with the representative of City of Tuzla as the owner of the distribution company and someone who has an impact on the changes in the legal framework and conditions in the Tuzla DH system. In addition to representatives of the authorities, the working group includes a representative of end consumers, those on which ultimately the implementation of improvement measures will be reflected. The LWG is also expanded with the director of Cestotehnik d.o.o. – a buildings manager company, who is some kind of connection between district heating company and end consumers. In this way, all parts of DH system were covered and identified stakeholders involved.

At meetings, it was managed to effectively communicate and discuss potential improvement measures based on credible information and experience of members of the LWG. Each meeting and conversation was very constructive in an atmosphere in which the will of all sides was expressed to improve the current heating system in Tuzla and raise it to a higher level.

The strategy for setting up groups was helpful in creating the working group, because the strategy somehow showed which actors should be involved in the LWG work, and methods how to get the best outcomes from the LWG meetings. Technical diagnostics and mapping the potential upgrading measures for Tuzla DH confirm justification of establishment a convenient LWG at the very beginning of the process and EPBiH warmly recommends the creation of such a LWG for any other upgrade DH project.

4 Global assessment experiences

In this chapter, the project partners from the demonstration cases share their experience of using the global assessment template of the Upgrade DH project (See ANNEX B, Chapter 9.1). Depending on the circumstances of the demo cases, different questions and aspects in the global assessment template were of varying relevance.

4.1 Bologna - Ferrara

Every process involving quantitative and/or qualitative data analysis adds value to the overall system's management, and the global assessment was no exception. At first it was a bit of an effort to gather all necessary data, yet it helped to focus on the overall picture when it came down to define perspective upgrading strategies.

Stakeholders' interviews were particularly important, providing very hands-on insights that contributed shaping, to a certain extent, the perspective upgrading strategy.

In conclusion, the global assessment and the stakeholder interviews are definitively to be advised. In fact, building up from data analysis and daily field experience leads to a sounder and more productive decision-making process.

4.2 Grudziadz

The potential upgrading measures have been identified by a working group that includes the OPEC-INEKO (Heat production) and OPEC-SYSTEM (Heat distribution and end use) and representatives of the consultant COWI.

The local group consists of five people covering the interests of the whole production and distribution system consisting of the following positions: DH senior specialist, DH Technical Director, Electrical power specialist, Laboratory Manager, Head of Electricity Department. The working group meetings have been helpful to identify main contents of master planning.

Termis software has been proven to be an efficient tool in the assessments of the networks responses to variations on the supply side.

4.3 Marburg

As mentioned in Chapter 2, the questionnaire of Annex B was a good starting point to discuss different aspects of the DH system in detail. Some of the questions were quite easy to answer, but others go far more into detail. Especially the performance indicator asking for the electrical power in kWh that will be spent for an MWh sold heat is an interesting value. When the amount of power is very high, it is an indicator that the pumps might not work efficient, the heat and water losses are high, or the hydraulics of the DH grid are worth to have a closer look on. In case some estimated values are calculated a bit too optimistic or some power consumers are not monitored (for example pumping sub stations) this value will be very low. Finally, the calculation of that value leads quickly to detailed discussions.

Guided by the "global assessment template" in Annex B, a discussion on the technical and non-technical aspects of the heat generation started. Together with information on the heat demand, a discussion of the most relevant and effective upgrade targets continued. The range of possibilities and options (some already in preparation, other ones need to be checked) became quite big. The whole DH system was discussed along the questionnaire, starting with possible operation strategies of the motor CHP and the buffer storage or the exchange substations with high influence on the temperature level of the grid. The collected options will be checked and ranked according to the specific boundary conditions and discussed on the working group, before more detailed analyses of selected measures will follow.

Not all questions could be answered, but the compact overview of many relevant details helped to understand the targeted DH system. The results from the questionnaire will be a starting point, followed by discussions and analysis with experienced people in that topic. As the way

of calculating certain values and DH systems in general are individual in the questionnaire, it cannot easily be used for a benchmarking to rate the performance or compare different DH systems.

4.4 Middelfart

COWI has the pleasure of being a house consultant for several years and has dialogue on a regular basis with the Director Jesper Skov and the operational staff. This means that the Upgrade DH initiative does not start from scratch. Therefore the proposed Upgrade initiatives must be seen as elements in a long row of subprojects.

Several topics have been dealt with over time and now the main concern is to expand the heat demand to neighbouring areas and to keep close eye to keeping the return temperature as low as possible at the consumers.

The system is a modern low temperature district heating system. Pipes (especially service pipes) are being replaced according to a yearly maintenance program as many of the pipes are old pre-insulated PEX flex pipes that in the beginning was not at the high quality that we see today – so predictive maintenance has also turned out to be an area to work further with.

The work in Middelfart has inspired a follower city Næstved to do same kind of analysis.

4.5 Purmerend

The potential upgrading measures have been identified by a working group that includes the Director, Technical Director and operational personnel of Stadverwarming Purmerend and representatives of the consultant COWI. This means that the Upgrade DH initiative is part of a long row of subprojects.

The interview tool has not made much difference. What gets things moving is to reach a common understanding of the challenges in the system and to use tool like Termis to clarify consequences of potential different changes.

Termis software has proven to be an efficient tool in the assessments of the networks response to variations on the supply side.

4.6 Salcininkai

“Salcininku silumos tinklai” (SSTINKLAI) produces, distributes heat to consumers. In addition, the company is responsible for the supervision of internal heating systems and substations in the buildings. SSTINKLAI operates all the information, necessary to prepare technical diagnosis and global assessment. The main stakeholder on current stage of the upgrading process is the local municipality as the main decision and policy maker. The support of local authorities in the implementation of more efficient heating solutions organized through the creation of a working group.

Representatives of Salcininkai District Municipality focused on these challenges related to the situation of district heating at the regional level:

- Actions are needed to accelerate the cost effective and energy efficient retrofitting existing inefficient district heating networks
- As necessary actions should consider interventions that are needed on the building side e.g. retrofitting and / or modifications of internal heat distribution systems and system and end user controls. The district heating supplier should also take into account the evolution of thermal demand in the future due to improving building energy performance standards and increased rate of building renovations.

The global assessment template helped to focus on the outcomes where they can make the greatest impact and avoid getting trapped making incremental progress against objectives that are no longer relevant.

4.7 Sisak

The global assessment of the Croatian demo case, the city of Sisak, has been performed with the help from the representatives of the district heating utility of the city. Both the representatives from the heat production company, HEP Proizvodnja, and the representatives from the heat distribution company, HEP Toplinarstvo shared their knowledge and data in order to provide the highest quality of the results.

In order to perform the assessment, the global assessment template has been used. The idea was to answer to as many questions as possible in order to increase the knowledge of the system in general. The structure of the template is clear and concise which enabled a fast completion of the task. Since the focus of the upgrading process in Sisak is the heat production side, the most important data that needed to be collected was on the heat production facilities. By answering the questions, the most important input data were gathered for the further analysis of the upgrading measures. However, the data on the heat distribution and end use side were also crucial for the analysis, giving the insight into the system as a whole and pointing out the main challenges.

As previously mentioned, the global assessment has been performed with the help of the representatives of the district heating utility in Sisak, which were interviewed as a part of the Stakeholder interview process. Due to the vast knowledge of the representatives, this enabled a complete understanding of the current situation and potential future steps. This is a recommended step for all the other entities who want to start an upgrading process, since acquiring the detailed knowledge of the existing system is always a first step in the process.

4.8 Tuzla

The Global Assessment Template has greatly facilitated the collection of data in the DH system Tuzla, as it at the same time includes the side of production, distribution and consumption of heat energy, and Interviews from all important stakeholders in the DH Tuzla system. The questions were particularly important because they chronologically provide answers to all the important details of the DH system from production to final consumers, especially those that treat technical and non-technical issues in the system. The answers to such questions in some way directed and pointed out the main problems in the system, especially if those problems were noticed by all parties. So the conducted Interviews in some way confirmed the issues which were maybe not so obviously visible from the obtained data presented in chapter General data sheet template.

EPBiH recommends interviewing identified stakeholders in order to get a better understanding of the situation and precisely determine possible upgrading measures and its implications.

5 Applied tools

Depending on the challenges, the involved partners and their strategy, the demonstration cases in this project have applied different tools. This chapter gives an overview of the tools that have been applied so far, with a short description of the tool, the expectancy and possibly first outcomes.

Demonstration case \ Tool	Bologna	Ferrara	Grudziadz	Marburg	Middelfart	Purmerend	Salcininkai	Sisak	Tuzla
Optits solution for energy production optimization	x	x							
Optit's solution for DHC network development		x		x					
Infoworks WS	x								
Optimization of pumping operations		x							
TERMIS software			x		x	x		x	x
TERMIS - Flow Temperature Optimization software			x		x	x			
LEANHEAT									
SCADA control system							x		x
qGIS								x	
Teleperm XP									x

5.1 Bologna

Optit's solution for energy production optimization

Hera managed a portfolio of plants not big enough to justify 24/7 in-place controlling, and planning was carried out on a weekly basis, leveraging mostly on the operators' experience. Within said framework, it was evident that it was not possible to take advantage of potential leverages for the daily energy production mix optimization.

The collaboration with Optit led to an innovative concept, envisioning a DSS which could optimize CHCP plants operations, integrating with field data and forecasting heat load, in order to maximize the system's operating margin.

Bologna Ecocity required the introduction of the explicit modelling and management of the thermal storage element, which presented some interesting optimization leverages, yet the pilot was successful and transitioned to the implementation in a production environment, finalizing the connection with SCADA systems.

Then, in 2016 Hera management started selling electricity on the market, rather than engaging with the Trading department, allowing for further optimization given the expected day-ahead electric prices profiles.

Finally, the adoption of the tool resulted in a more dynamic short and long-term management, yielding an increased operational margin, as well as an improved management of CHP assets and a more dynamic use of the thermal storage, thus minimizing the carbon footprint.

In UpgradeDH, it will be considered an evolution of the tool in order to consolidate the process and improve the overall end-to-end management.

Infoworks WS

Network operations present daily challenges, due to the continuously changes in the asset configuration (e.g. due to breakages or scheduled maintenances). Also, planning activities for network development require complicated thermal-hydraulic analyses.

Various activities carried out by Hera's personnel could benefit from the availability of a hydraulic simulation tool:

- Design analyses, for proper dimensioning and for benchmarking of different layout hypotheses;
- Operational analyses regarding potential critical situations (foreseeable and extraordinary);
- Management analyses, regarding the impact of different maintenance plans, in order to minimize disservice.

The tool for the specific purpose was identified in Infoworks WS, a GIS-based thermal-hydraulic simulator, allowing for the modelling of the system up to the single network element, for which extensive configuration is possible.

The adoption of the tool resulted in an improved planning capability, reducing disservices due to ordinary and extraordinary maintenance and refining design analyses.

5.2 Ferrara

Optimization of pumping operations

The aim of the upgrading process was to reduce the network supply pressure, yet assuring that the customers were served properly. Many critical points in the networks were equipped with SCADA (Supervisory Control and Data Acquisition) systems to monitor differential pressure and supply temperature.

Over the years, Hera's operators developed a heuristic table yielding the target supply pressure, depending on outdoor temperature and time of the day.

Then, a new regulation strategy for the pumping station was implemented, governing the VSD (Variable Speed Driver) pumps operations depending on the measurement of the pressure drop at the most critical user, so that in this site the pressure drop could approach as much as possible the minimum value of 1 bar.

The supply pressure profiles analyses showed that a reduction up to 2-3 bar had been achieved, compared to previous years. Consequently, the mechanical losses associated with the throttling process (i.e. mainly the control valves) in all substations lessened, as well as the pumps' power absorption.

The annual electrical saving has been estimated up to 75 TOE (tons of oil equivalent) per year.

Optit's solution for energy production optimization

Hera managed a portfolio of plants not big enough to justify 24/7 in-place oversee and planning was carried out on a weekly basis, leveraging mostly on the operators' experience. Within said framework, it was evident that it was not possible to take advantage of potential leverages for the daily energy production mix optimization.

The collaboration with Optit led to an innovative concept, envisioning a DSS which could optimize CHCP plants operations, integrating with field data and forecasting heat load, in order to maximize the system's operating margin.

Even though Ferrara's case was not a traditional CHP plant, thus requiring some modelling customizations, the successful pilot transitioned to the implementation in a production environment, finalizing the connection with SCADA systems.

Then, in 2016, the Hera management started selling electricity on the market, rather than engaging with the Trading department, allowing for further optimization given the expected day-ahead electric prices profiles.

Finally, the adoption of the tool resulted in a more dynamic short- and long-term management, yielding an increased operational margin, as well as a maximization of the RES production, thus minimizing the carbon footprint.

In UpgradeDH, it will be considered an evolution of the tool in order to consolidate the process and improve the overall end-to-end management.

Optit's solution for DHC network development

Ferrara DH network presented a saturated production capacity, in relation to the installed substations' nominal power. Yet, a total load much lower was being actually recorded, indicating that several customers did not really require the contractual load.

Optit presented its solution for DHC network development, which defines the optimal district heating network strategy for its expansion, finding the best compromise between business/economic drivers (NPV maximization) and technical constraints (thermal-hydraulic feasibility).

For the specific Ferrara's case, the solution was customized in order to include a functionality allowing to determine the optimal scenario of recontractualization among existing customers, whose substations may be effectively resized.

The adoption of the tool resulted in the structuring of a commercial campaign that, requalifying some existing customers' contract, freed up capacity at generation level, which was to be used to connect additional customers for further network saturation. Thus, the process allowed to maximize the production assets' capacity in terms of sales revenues, as well as deepen ever more the penetration of DH in the local heating market.

5.3 Grudziadz

Termis software

Termis is a hydraulic modelling tool used for DHC, which simulates flow, pressure and thermal behaviour in the distribution network.

OPEC-SYSTEM in Grudziadz is using Termis off-line solution since 2005. This tool allows to calculate all parameters over the network and is used for planning, rehabilitation and reinforcement.

Termis is used for designing District Heating Networks, to meet future demands, avoid bottlenecks and comply regulations.

In Grudziadz, Termis is used for calculating flows, temperatures, pressures, pumping head, load on pipes, pressure loss gradients, temperature losses, pressure losses, costs, renovation plans etc.

The District Heating network in Grudziadz suffers with lack of differential pressure in some network branches. That issue is reflected in Termis calculations and will be a matter of further investigations with preferred solution to be DP regulators in the house substations.

More, OPEC-SYSTEM is willing to develop their Termis solution including SCADA measurements to obtain more information about their entire network and operation. This would allow them to make smarter and better decision making leading to optimizing cost-effectiveness and overall efficiency.

TERMIS - Flow Temperature Optimization software

Flow Temperature Optimization (FTO) is a software that optimizes the supply temperature at the heat plants. Termis FTO uses real time hydraulic networks that ensures the costumer correct time delays, heat accumulation to cover morning peak loads, correct heat loss and optimization of multiple heat sources. The Termis FTO model provides the costumer with a detailed model of the minimum supply temperature at the consumers which is based on the outdoor temperature, maximum and minimum inlet temperature at plants, maximum rate of change of inlet temperature at plants and maximum flow capacity at heat plants and pumps in the network.

The result of tests driven with FTO on Grudziadz network clearly show that there is a potential for heat losses savings by optimizing the parameters into the DH network such as supply temperature and flow adjustments.

5.4 Marburg

Optit` s solution for DHC network development

Optit` s solution for DHC network development will be used to receive reliable information on the hydraulic status and changes associated with various adjustments. Caused by some issues in the confidentiality management and the integrity of the data this took more time than expected. As now all data should be available and will in the next steps be correctly compiled and prepared the tool will be used.

LEANHEAT, TERMIS

Depending on the results of the hydraulic calculation and the access to the other software tools their application will be checked. At the moment the use of tools for peak power optimisation (LEANHEAT), flow and return temperature optimisation (TERMIS), production optimisation (Optit) or economical future scenario calculation seems to be relevant.

5.5 Middelfart

Termis software

Termis is a hydraulic modelling tool used for DHC, which simulates flow, pressure and thermal behaviour in the distribution network. Termis off-line solution allows to calculate all parameters over the network and is used for planning, rehabilitation and reinforcement. Termis is used for designing District Heating Networks, to meet future demands, avoid bottlenecks and comply regulations.

In Middelfart, Termis is used for calculating flows, temperatures, pressures, pumping head, load on pipes, pressure loss gradients, temperature losses, pressure losses, costs, renovation plans etc.

The District Heating network in Middelfart can be improved with RTO (return temperature optimisation). Middelfart Fjernvarme is willing to develop their Termis solution including SCADA measurements and 2-way meter readings to obtain more information about their entire network and operation. This would allow them to make smarter and better decision making leading to optimizing cost-effectiveness and overall efficiency.

TERMIS - Flow Temperature Optimization software

Flow Temperature Optimization (FTO) is a software that optimizes the supply temperature at the heat plants. Termis FTO on-line uses real time hydraulic networks that ensures the costumer correct time delays, heat accumulation to cover morning peak loads, correct heat loss and optimization of multiple heat sources. The Termis FTO model provides the costumer with a detailed model of the minimum supply temperature at the consumers which is based on the outdoor temperature, maximum and minimum inlet temperature at plants, maximum rate of change of inlet temperature at plants and maximum flow capacity at heat plants and pumps in the network.

The result of tests driven with FTO show that there is a potential for heat loss savings by optimizing the parameters into the DH network such as supply temperature and flow adjustments.

5.6 Purmerend

Termis software

Termis is a hydraulic modelling tool used for DHC, which simulates flow, pressure and thermal behaviour in the distribution network. Termis off-line solution allows to calculate all parameters over the network and is used for planning, rehabilitation and reinforcement. Termis is used for designing District Heating Networks, to meet future demands, avoid bottlenecks and comply regulations.

In Purmerend, Termis is used for calculating flows, temperatures, pressures, pumping head, load on pipes, pressure loss gradients, temperature losses, pressure losses, costs, renovation plans etc.

The District Heating network in Purmerend suffers with lack of differential temperature/ main lines. That issue is reflected in Termis calculations and will be a matter of further investigations with preferred solution to be DP regulators in the house substations and return temperature optimisation.

More, Purmerend is willing to develop their Termis solution including SCADA measurements to obtain more information about their entire network and operation. This would allow them to make smarter and better decision making leading to optimizing cost-effectiveness and overall efficiency.

TERMIS - Flow Temperature Optimization software

Flow Temperature Optimization (FTO) is a software that optimizes the supply temperature at the heat plants. Termis FTO uses real time hydraulic networks that ensures the costumer correct time delays, heat accumulation to cover morning peak loads, correct heat loss and optimization of multiple heat sources. The Termis FTO model provides the costumer with a detailed model of the minimum supply temperature at the consumers which is based on the outdoor temperature, maximum and minimum inlet temperature at plants, maximum rate of change of inlet temperature at plants and maximum flow capacity at heat plants and pumps in the network.

The result of tests driven with FTO show that there is a potential for heat loss savings by optimizing the parameters into the DH network such as supply temperature and flow adjustments.

5.7 Salcininkai

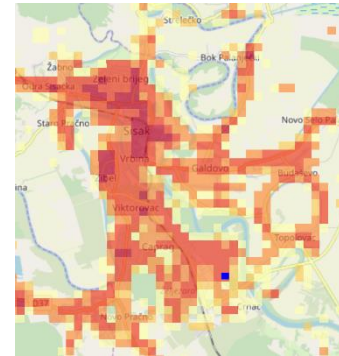
SCADA control system

Our control system for boiler plant in Salcininkai city is automated; therefore, the devices can operate in an automatic mode without the need for constant operator supervision. The technological process visualisation system (SCADA) facilitates the operation of the boiler plant, as well as allowing the operator to monitor the status of the devices and to generate fault reports. All of the technological measurements, equipment status details, events, incidents and accidents are displayed on the operator's panel and in a computer located in the operator's workplace, as well as being stored in the system's memory.

5.8 Sisak

qGIS

In order to map the heat demand of the city of Sisak, the qGIS tool was used. The method for heat demand mapping has been previously developed by the UNIZAG FSB, using the top down method for geographically allocating the aggregated data on the national level. The results of the mapping process show the parts of the city which show high perspective for connection to the district heating network. The highest heat demand densities are in the old city of Sisak, north of the river Sava, as can be seen on the map. Therefore, the expansion to this part can be shown as a priority in the future development of the city. This has already been communicated with the district heating distribution company, which is highly motivated to perform this step. However, due to the proximity of the heating plant (blue dot) to the neighbourhoods of Budaševo and Topolovac, expanding the connection to cover the demands in these parts of the city can also be considered in the future.



TERMIS

TERMIS tool has just been recently installed at the premises of the heat distribution company HEP Toplinarstvo. At this moment, the model is being validated, i.e. the comparison between the model and the real state of the network is being performed. The overall goal of using this tool is to enable the main heating station to operate completely automatic and that the system operates in an optimal manner, that way rationalising the energy consumption of the overall system. The tool has also been used for the district heating expansion scenario analysis, enabling the decision makers from the distribution company to get the optimal design parameters of connecting new consumers in a significantly reduced time. Specifically, the first part of the analysis is for connecting the two new large consumers in the next couple of years, which will facilitate the expansion towards the old town of Sisak and a major increase in the number of connected consumers.

5.9 Tuzla

Teleperm XP

Using Teleperm as a process monitoring software tool and all parameters on the production side, it was noted that the data relating to the district heating system in Tuzla, primarily thinking about the flow, reach their maximum. However, this applies only when it comes to the heat energy delivery, while in the cogeneration thermal blocks there are more heat reserves. Since the limits in transport reach the regulation of the system and the regime it is possible to perform only by temperature regulation, because the flow rate is the maximum (constant). Bearing in mind that the DH system Tuzla has a tendency to expand and constantly connect new consumers, it is clear that something will have to be done on this issue. There are several ideas, for example:

- the replacement of the current main gas line with a large diameter pipeline
- regulating consumption on the end users' side
- increasing the energy efficiency of residential buildings in order to reduce the losses in the final consumption significantly, and thus left space for expansion of the district heating network with the heat capacity which is currently available.

SCADA and Termis

In the past 10 years information technology (IT) has been gradually implemented in the entire system of DH Tuzla. This includes remote control and management of district heating systems, SCADA - supervisory, control and data acquisition and Termis - the district energy networks simulation platform for improving system design and operation. The performance analysis of a district heating system is very important.

In order to have quality analysis, it was necessary to build in heat meters in all heating substations with heating problems. With data from heat meters, it was able to get partial picture of the flow and pressure distribution in the part of the district heating system. Hot spots were defined but it was not enough information for implementation of the proper solution. Next step was to connect hot spots to the SCADA system in order to get easier data updating and screening. At same time, system regulation (flow and pressure) was started in the west part of the system where operating conditions were much better.

All these activities have been followed up the real time analysis and improving operation of the district heating system with Termis. By using live SCADA data, the Termis model was transformed from a planning tool to a decision-making tool, integrated in day-to-day operations – with instant and clearly identified benefits and economic advantages. With sufficient number of these data process control is not just watch and react, which is common with a lot of district heating systems, but set up terms for analyses of current condition and prediction of possible changes in the system. All these enable instant reaction for proper and efficient system management.

Taking in account purpose of the city of Tuzla context and its sustainable energy strategy vision, it has developed the overall project idea and identified the following key project components:

- Optimisation of existing district heating system with the aim to improve energy efficiency performance of the system itself, in order to expand its capacity for connecting new heat energy consumers;
- Connection of individual residential housing units to the district heating system, which includes creation of required technical and financial conditions for new connections of houses located in suburbs of Tuzla, thus enabling these households to stop using coal-based heat energy;
- Replacement of current coal-based heating in individual residential houses with biomass which includes creation of technical and financial conditions enabling

individual households in rural parts of Tuzla municipality to start using biomass (pellet) for heating, thus abandoning coal-based heating;

- Expansion of district-heating network by extending it over the Tuzla town hilly outskirts with the aim to create technical conditions for new connection on the district heating of houses located in this area;
- Applying energy efficiency measures on public buildings owned by the Tuzla Municipality in order to generate energy-related and financial savings by reducing energy consumption.

The climate changes, implementation of IT and detailed analysis pointed out the demand for revision of all system. The following upshots came up as the result of such thinking:

- It is possible to convert/extend the existing DH grid to the lower temperature DH concept, a significant reduction in the distribution heat losses is gained by the introduction of lower temperature DH and thermal storage will be a necessity in future energy systems.
- Integration of energy sources to energy users could provide optimum solutions for the reduction of primary energy use, the increased uptake of locally available sources of renewable fuels and residual heat from electricity generation. Hence, EPBiH very recommends the integration and application of SCADA and Termis.

6 Potential upgrading measures

The upgrading measures that are considered in the different demonstration cases are listed in this chapter.

6.1 Bologna

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Further development of energy production optimization (Optit)	Analyses of opportunities stemming from new regulation	Production side	Evolution and development of the current implemented optimization software	<ul style="list-style-type: none"> • Manual and automatic infra-day re-optimization process • Manual and automatic infra-day update of the forecasted profiles • Improved asset modelling and configuration • Environment featuring the conditions to interface with trading processes of portfolio management linked to balancing markets.
2	Installation of heat pumps in Bologna Berti system	Analyses of improved flexibility in a highly integrated system	Production side	Technical analyses and potential infrastructural follow-up	<ul style="list-style-type: none"> • Maximization of the operational range of CHP units, thus reducing the use of gas boilers and increasing the overall system's efficiency • Additional heat recovery from CHP assets, otherwise destined to be unexploited • Improved operational and strategic flexibility for more dynamic interaction with electricity markets
3	Smart Substations Analytics (project SmartTLR)	Analyses on the status of digitalization at system's level	Customers' side	Infrastructural investments and subsequent applied analytics on gathered data	<ul style="list-style-type: none"> • Knowledge of the single users and their potential clustering • Optimized centralized and decentralized pumping • Environment featuring the conditions for potential demand side management.

6.2 Ferrara

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Evolution of solution for energy production optimization (Optit)	Analyses of opportunities stemming from new regulation	Production side	Evolution and development of the current implemented optimization software	<ul style="list-style-type: none"> • Manual and automatic infra-day re-optimization process • Manual and automatic infra-day update of the forecasted profiles • Improved asset modelling and configuration • Environment featuring the conditions to interface with trading processes of portfolio management linked to balancing markets.
2	Connection of potential new low-enthalpy customers	Analyses on the residual sustainable potential of the geothermal source	Network side	Technical analyses on potential new network configurations	<ul style="list-style-type: none"> • Maximization of heat supply exploitation (i.e. ΔT between supply and return) • Improved extraction capability from geothermal source, thus contributing towards a reduced environmental impact • Advantageous tariff for low-enthalpy users
3	Smart Substations Analytics (project SmartTLR)	Analyses on the status of digitalization at system's level	Customers' side	Infrastructural investments and subsequent applied analytics on gathered data	<ul style="list-style-type: none"> • Knowledge of the single users and their potential clustering • Optimized centralized and decentralized pumping • Environment featuring the conditions for potential demand side management.

6.3 Grudziadz

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1a	Plan for increased share of renewables	Information campaigns	Production/ End use	Make people convert from individual fossil fuel firing to green district heating	Reduced emissions Increased heat market for the utilities
1b	Heat accumulator tank for load levelling.	Construct heat accumulator	Production side	Analyse, design and tender	Load levelling leading to more stable boiler operation
2a	Heat loss reduction by better supply and return temperature management with temperature optimization	Termis model and 2 way meters	Distribution side	Use Termis real-time model for flow temperature optimisation Use energy meter readings to identify consumer with poor return temperature and help them to solve the problem causing it	Reduced heat loss and better system balance Reduced emissions
2b	Increase the number of pre-insulated pipes in the system	Historical data, local knowledge of the DH system and Termis model to identify need for replacements	Distribution side	Identify old pipes, pipes with high energy loss and undersized pipes to be replaced.	Reduced heat loss and better system balance Reduced emissions
3	Replacement of local gas boilers for HTW with District Heating HTW units is recommended.	See 1a above	Production side	Make people convert from individual fossil fuel firing to green district heating	Reduced emissions Increased heat market for the utilities

6.4 Marburg

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Lower the return temperature	Comparison of different return temperature levels	End use	Replace old substations	Improve the efficiency of the big customers
2	Lower the electrical demand by optimising the pump operation	Evaluation of kWh _{el} /MWh _{th} in the network (Global assessment question)	Production side	Develop an efficient monitoring strategy to improve the pump regulation	Reduction of pumping costs
3	Optimise the plant operation	Discussions during the local working group meetings	Distribution side	Simulation of different energy sources Simulation of storage integration Economical calculation of some P2H Secondary grid options/ Return flow as heat source.	Increased the heat demand during summer
4	Calculate economic feasibility of a P2H unit	Discussions during the local working group meetings	Production side	Gather performance options Collect missing boundary conditions Start an economical calculation	Support a decision process
5	Expansion strategies	Discussions during the local working group meetings	End use	Find easy accessible expansion areas (depending from heat demand and grid) Strategic replacement of bottleneck pipes Recommendations for priority investment plans	Increase the performance of the system by supply more customers with same input

6.5 Middelfart

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Convert CHP plant from coal to biomass	Separate project	Production side	Middelfart Fjernvarme Amba will use the produced heat.	Reduced emissions.
2	Optimise grid maintenance	Combine online Termis model with real time meter readings.	Production side	Develop and test the diagnostics / planning method	Better utilisation of maintenance budget and reduced heat loss.
3	Merger with the neighbouring utility Ejby Fjernvarme Amba.	Legal consultancy and organisational changes	End use	Implement organisational change and connect Ejby with transmission line.	Increased heat demand (income) and more economic administration

6.6 Purmerend

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Energy demand prognosis 2018 - 2030	Subproject, forecasting energy demand in selected districts	Production side/ End use	Make consumers convert from individual fossil fuel firing to green district heating. Set demands for DH in local development plans.	Increased heat market for the utility Reduced emissions on global scale as individual gas boilers are converted
2	New biomass plant	Subproject, review of tender material for new bio-waste central	Production side	Prepare for condensing mode	Better boiler efficiency, reduced cost of operation
3	Heat accumulator tank for load levelling.	Construct heat accumulator	Production side	PID and functional specs of new pumps and buffer tank 3	Load levelling leading to more stable boiler operation
4	Hydraulic optimisation of main DH line	Termis optimisation	Distribution side	Termis optimisation	Increased capacity of existing pipe
5	Introduction of SlimNet (twin pipes) instead of traditional single pipes	Data, local knowledge of the DH system and Termis model to identify need for replacements	Distribution side	Identify old pipes, pipes with high energy loss and undersized pipes to be replaced.	Reduced heat loss and better system balance Reduced emissions
6	Heat loss reduction by better supply and return temperature management with temperature optimization,	Termis model and 2-way meters	Distribution side/ End use	Use Termis real time model for flow temperature optimisation Use energy meter readings to identify consumer with poor return temperature and help them to solve the problem causing it	Reduced heat loss and better system balance Reduced emissions
7	Replacement of local gas boilers with District Heating	Campaign, local dev. plans	End use	Make consumers convert from individual fossil fuel firing to green district heating	Reduced emissions Increased heat market for the utilities

6.7 Salcininkai

No.	Upgrading measure	Method employed	Implementation location	Way of implementation	Expected benefits
1	Network optimization in order to reduce operational costs	Using other district heating networks experience, economical realization data and company's experience.	Distribution side	Use of software/experience to optimize the network for today's and/or future demand. Use the calculations to implement	Reduced heat loss, electricity consumption etc.
2	Solar thermal implementation in a small system which can operate during summer months and replace main heating source in Salcininkai city	Preliminary solar heating analysis; global solar irradiation measurements;	Production side	Construction of solar thermal collector array	Reduced heat production costs.
3	Installation of thermal heat storage to increase flexibility	Operational experience, practical examples in other systems.	Production side	Construction of a thermal storage	Reduced greenhouse gas emissions, increased renewable energy generation share.
4	Heat recovery from the flue gas	Heat pump implementation analysis	Production side	Installation of a heat pump	Reduced greenhouse gas emissions, increased renewable energy generation share. The flue gas temperature would be reduced from 50°C down to 20-30°C degrees.

6.8 Sisak

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Integration of solar energy in the heat production mix	Analysing the solar irradiation at the site, defining the available space for the installation of this system	Production side	Installing the flat plate solar collectors on the old management building which is currently completely unutilized	<ul style="list-style-type: none"> • Increasing the share of renewables in the heat generation mix • Increasing the public opinion towards the district heating system in Sisak • Decreasing the costs of the heat being supplied to the consumers
2	Integration of the thermal storage system at the heat production side	Monitoring the regular operation of the system, learning from the base practice examples of the upgraded project	Production side	Installation of the heat storage system in a form of a buffer tank	<ul style="list-style-type: none"> • Reducing the number of times the auxiliary boilers are turned on • Reducing the natural gas consumption • Lowering the emissions of the pollutants into the atmosphere • Increasing the overall economic and technical efficiency of the system
3	Waste heat utilization from the condensate for the technological purposes in the system	Monitoring the regular operation of the system	Production side	Using the waste heat to preheat the feed water for the cogeneration units, connecting the condensate storage with the thermal storage when it is built and therefore using its excess heat for heating the consumers	<ul style="list-style-type: none"> • Using the heat from another process is avoided and therefore the fuel consumption is lower • Decreasing emissions of the pollutants and increasing the efficiency of the process • Significantly lowering heat losses of the condensate storage

6.9 Tuzla

No.	Upgrading measure	Method employed to find the measure	Implementation location	Way of implementation	Expected benefits
1	Operation optimization of the two cogeneration units in TPP Tuzla	Operational experience supported by Teleperm XP.	Production side	Use of applicable software tools to match production, consumption and prices better.	Increase the energy efficiency and reduce the primary energy demand on the production side of the TPP Tuzla.
2a	Integration of renewable energy sources in the heat production portfolio of the DH system Tuzla - solar collectors and photovoltaic panels	Indicative solar indicator analysis; global solar radiation measurements; site visits performed; integration of best practice examples into the DH Tuzla system, discussions and site visits with AGFW experts.	Production side	Perform simulations and feasibility assessment of integrating solar collectors and PV and based on outputs, construct them, accordingly.	Increase in RES share, decrease the use of coal and improve environmental aspect of the DH system.
2b	Integration of renewable energy sources in the heat production portfolio of the DH system Tuzla – waste incinerator construction	Indicative analyses on waste potential availability; integration of best practice examples into the DH Tuzla system.	Production side	Perform simulations and feasibility assessment of integrating waste incineration plants and based on outputs, construct them, accordingly.	Increase in RES share, decrease the use of coal and improve environmental aspect of the DH system.
2c	Integration of renewable energy sources in the heat production portfolio of the DH system Tuzla - biomass usage	Indicative analyses on biomass potential availability; pilot projects on co-firing with biomass performed on similar thermal unit in Bosnia and Herzegovina; integration of best practice examples into the DH Tuzla system.	Production side	Perform simulations and feasibility assessment of integrating standalone biomass boilers and/or usage of biomass in the co-firing mode and based on outputs, construct them, accordingly.	Increase in RES share, decrease the use of coal and improve environmental aspect of the DH system.

3	Integration of heat storage	Integration of best practice examples into the DH Tuzla system.	Production side	Perform simulations and feasibility assessment of integrating heat storage systems and based on outputs, construct them, accordingly.	Increase flexibility of the system and reduce primary energy demand.
4	Replacement of the existing main circulation pump with new electronic frequency regulated circulation pumps for each DH system separately	Discussions and site visits with AGFW experts and constancy through webinar (Task 3.4)	Production side	Replacement.	Savings in electricity consumption, and thus decrease in CO ₂ and hydraulic issues resolving.
5	Replacement of existing hot water pipeline (DN600) with a pipeline of a larger diameter Solving hydraulic problems	Operational experience supported by Termis and SCADA. Consultancy through webinar (Task 3.4)	Distribution side	Replacement.	Availability of greater thermal power.
6	Replacement of remaining circulation pumps with new electronic frequency regulated circulation pumps	Operational experience supported by activities performed so far.	Distribution side	Replacement.	Savings in electricity consumption, and thus decrease in CO ₂ and hydraulic issues resolving.
7	Sanitary water delivery and/or cooling services	Integration of best practice examples into the DH Tuzla system. Consultancy by AGFW experts during their stay in Tuzla	Consumer side	Precisely identify consumption perform simulations and feasibility assessments and establish the conceptual design. Based on outputs, construct the needed elements of the system, accordingly.	Improvement of the efficiency of the entire system; Coal consumption reduced and the negative impact on the environment would be reduced. Expanding the system`s services by sanitary water delivery will make a good prerequisite for the integration of solar thermal

					collectors and their usage within the DH Tuzla system.
8	Energy efficiency measures at residential buildings	Indicative energy audits performed; operational experiences; conducted surveys and interviews with end users performed; integration of best practice examples into the DH Tuzla system.	Consumer side	<p>Install thermostatic valves for heating room temperature regulation;</p> <p>Change the current method of consumed heat energy charging.</p> <p>Perform end user educations on energy savings and its benefits.</p> <p>Renovation of existing building stocks.</p>	Savings in consumption, reduction of the primary energy demand and thus decrease in CO ₂

7 Summary

This chapter documents the experiences made by the demonstration cases during the assessment and diagnosis of the DH networks.

7.1 Bologna - Ferrara

Hera has been fruitfully collaborating with Optit for various years, leveraging on Optit's expertise on analytics and optimization for pilot projects regarding DH network development and production assets scheduling. The latter is now utilized for the automatized daily operations optimization for the majority of Hera's DH plant portfolio, supporting the company in the path of digitalization of its management processes.

The multi-stakeholder approach comprising a global assessment, stakeholders' interviews and working group meetings helped identifying potential upgrading measures that would enhance the overall performances of the systems.

For all demo cases in Bologna and Ferrara it was envisioned possible interventions on the production and customers' side:

- The evolution of the solution for energy production optimization already implemented in Hera's systems, determined by analysing the potential opportunities of more dynamic optimization processes, also stemming from new Italian regulation regarding electricity markets.
- The application of Smart Substations analytics, determined by analysing the digitalization status at a system's level, foreseeing infrastructural investments and application of analytics methodologies to extract value from the data at the users' premises.

For the specific case of DH network Bologna Berti, it was analysed how to improve production flexibility in a highly integrated energy system, with heat/chill/electricity provision. It was suggested that the installation of heat pumps would constitute a potential upgrading measure, in order to maximize CHP operations. Therefore, technical analyses and a potential infrastructural follow-up was foreseen within the project.

For the specific case of the DH network in Ferrara, it was analysed how to exploit the residual geothermal potential, yet in a sustainable way in terms of source long-term integrity. It was suggested that connecting low-enthalpy customers would allow to enhance the geothermal extraction capability, thus contributing towards a reduced environmental impact and maximizing the heat supply efficiency.

7.2 Grudziadz

The potential upgrading measures have been identified by a working group that includes the OPEC-INEKO (Heat production) and OPEC-SYSTEM (Heat distribution and end use) and representatives of the consultant COWI.

The local group consists of five people covering the interests of the whole production and distribution system consisting of the following positions: DH senior specialist, DH Technical Director, Electrical power specialist, Laboratory Manager, Head of Electricity Department.

The identified potential upgrading measures are in short:

1. Heat production: Plan for higher renewables share and implementation of heat accumulator tank for load levelling.
2. Heat distribution: The focus should be on heat loss reduction by better supply and return temperature management with temperature optimization, better balance of the DH system, and to increase the number of pre-insulated pipes in the system
3. End use: The main concern in Grudziadz is the way to reduce the air pollution caused by local stoves and boilers fired with coal, wood and waste. Air quality would improve by more district heating connection and coal fired boilers replacement with fossil free or at

least gas boilers. Replacement of local gas boilers for HTW with District Heating HTW units is recommended.

7.3 Marburg

The AGFW has regular contacts with DH operators. Still, this project leads to a deeper knowledge of the ongoing activities and issues the supplier is dealing with. Especially in Germany, where the political strategies and requirements lead to quite challenging tasks for the future operation of DH grids, such a knowledge and activity exchange is important. As the city of Marburg supports the environmentally friendly targets and will go forward as a pioneer, the responsible people are looking for upgrading measures in the whole system. As the daily business, to run the DH system, is already a fulltime job, the implementation of feasibility studies and calculation of different options is additional work. During the meetings of the LWG it turned out quite clearly that there is a lot of experienced staff knowing quite well on the bottlenecks of the system and already work on different solutions to overcome identified issues. Even though all DH systems are individual, an experienced project consortium, as the one available in the Upgrade DH project, can help to identify issues and develop possible solutions more efficient. Sometimes, the experience exchange itself and also the previous collection of details for upcoming discussions lead to new ideas and possible solutions.

Supported with the knowledge of the Upgrade DH experts, the relevant questions were collected in the questionnaire of Annex B, which turned out to be an easy and structured way to cover most topics of a DH system in detail. In combination with the meetings at the places where the DH system is operated, controlled and monitored the picture of the current situation of the DH system became quite clear. This was also the experience in Tuzla, where AGFW supported the activities of the LWG.

The tool of digital monitoring of DH systems leads to more detailed data of the operation mode and current status. The collection of best practice examples and tools will also offer options to analyse the systems and develop possible optimisation and forward-looking strategies. The benefit of these activities can first be harnessed when the data can be interpreted. Interpretation can be easier and better if experience is exchanged and discussions between partners are supported. However, the physical inspection of the equipment will still be an important part for the identification of upgrading measures and retrofitting activities.

At the moment the preparation seems expedient and promising. However, a final evaluation can only be carried out at the end of the project or after the implementation of individual measures.

7.4 Middelfart

The potential upgrading measures have been identified by a working group that includes the Director, Technical Director and operational personnel of Middelfart Fjernvarme Amba.

The identified potential upgrading measures are in short:

1. Heat production: Convert CHP plant from coal to biomass.
2. Heat distribution: Optimise grid maintenance and collaborate with Næstved Fjernvarme Amba DH utility on the same issue (follower city)
3. End use: Merger with the neighbouring utility Ejby Fjernvarme Amba.

7.5 Purmerend

The potential upgrading measures have been identified by a working group that includes the the Director, Technical Director and operational personnel of Stadverwarming Purmerend and representatives of the consultant COWI. This means that the Upgrade DH initiative is part of a long row of subprojects.

The identified potential upgrading measures are in short:

1. Heat production: Plan for new consumers, higher renewables share and implementation of heat accumulator tank for load levelling.
2. Heat distribution: Optimise grid operation in respect to better supply and return temperature management with temperature optimization, better balance of the DH system, and to increase the number of pre-insulated (twin) pipes in the systems sub districts.
3. End use: The main concern in Purmerend is too high and increasing return temperature and leakages at household levels.

7.6 Salcininkai

Organization of working groups lead to a comprehensive assessment of the current situation and identification of possible upgrading measures. The working groups involved all essential stakeholders in order to ensure the identified upgrading measure success during the further steps. The working group meetings discussed about the possible tools and methods that are necessary for implementation of the identified upgrading measures.

Solar thermal integration and network optimization was main but not the only upgrading measures that working group highlighted. Communication between different demo case partners resulted in valuable experience sharing. Moreover, some of the partners actively propose some solutions that company may try during the upgrading process.

The working groups accelerated the performance improvement and the ability to continuously adjust depending on the reachable outcomes. The meetings focused on the greatest impact and on the avoidance of getting trapped on the objectives that are no longer relevant during incremental progress.

7.7 Sisak

The aforementioned upgrading measures for the district heating system of Sisak have been identified as a part of the well-structured process defined throughout the Workpackage 3 of the UpgradeDH project. The first step in the process was to form the working group, which consisted of the representatives of the heat production and distribution companies. The recommendation is to include people with the widest knowledge of the existing system in order to define the gaps. In this case, these were the directors of both companies. Furthermore, the global assessment of the existing system has been carried out with the help of the working group representatives, which helped to define the focus areas of the upgrading process.

Taking into account that the distribution and end use side have been recently refurbished, the focus has been put on the heat generation side. In order to specify the exact upgrading measures which should be further analysed, the interviews with the main stakeholders have been implemented. This included both the representatives of the production and the distribution company. Finally, the most critical upgrading measures have been defined and agreed for the further analysis.

All the steps, i.e. setting up the local working groups, performing the global assessment, interviewing the relevant stakeholders, and having regular working group meetings have proven to be rather significant and the integral part of the process in order to clearly define the upgrading measures, minimizing the needed time for the identification.

7.8 Tuzla

In the case of the DH system Tuzla, the methodology proposed within the Upgrade DH project was followed from the very beginning and showed up as very helpful in identifying first investigation lines for upgrading purposes.

Establishment of the LWG with relevant members can be highlighted as one of the key actions within in the process of identifying possible investigation lines. Engagement of competent

people who are familiar with the DH system and who can make a contribution based on their work experience and eventual application of available software tools within their fields of expertise, as well as those who can influence the implementation of certain decisions, can be considered a promising step towards a successful upgrading measure realisation.

Involvement of experienced experts from the Germany association AGFW through their expert coaching and presence on site has also greatly contributed to the identification of upgrading measures and possible resolution of observed problems, especially related to hydraulic issues.

8 Annex A: Strategy for setting up groups

As part of the UpgradeDH project, local working groups were formed. Recommendations (listed below) were prepared to facilitate the organisation of the working groups for the different partners.

For the success of an upgrading process of a DH system, it is important that all stakeholders are involved from the beginning of the process to ensure acceptance of the future project. Therefore, local working groups will be created for each demonstration case, which will be involved in the assessment phase, but also in the whole upgrading process.

For each demo case, a report will be elaborated on the composition of the working groups, meetings, discussions and outcomes.

8.1 Should a working group be set up as a new one 'from scratch' or should an already existing one be 'used'?

This depends on the specific situation in the region. At places where e.g. advisory or working groups on DH issues already exist, these groups can be used and new members can be added. Reason is the benefit from expertise and networks already created by the working group. Furthermore, subgroups can be selected for addressing more specific issues, e.g. heat suppliers and developers for addressing market needs or energy agencies for developing promotion and advisory activities.

In regions where no similar groups exist so far, the working group has to be set up from scratch. Another possibility in this case is to check the situation on national level, as especially in smaller countries this might help to use synergies with groups from other regions or acting on national level.

8.2 Who should be invited or asked for participation and why?

Relevant stakeholders that could be invited for participation are the following:

- Supply and demand side

Heat suppliers, DH grid operators, energy cooperatives, energy initiatives, municipalities, housing associations, building owners and end users

- Practical supporting actors

Suppliers, planners, city planners, experts in heat planning, banks, financiers, energy agencies and R&D organizations

- Political supporting actors

Politicians, parliamentarians, authorities, local policy makers such as city and administration and associations of above mentioned stakeholders

In general it is important to cover the whole value chain of heat generation, heat distribution and heat use. Furthermore beside the above mentioned stakeholder groups, the working group can be kept open for new stakeholders that actively ask for being involved in the activities.

8.3 How often should the working group meet and how can a regular participation of the persons be ensured?

Meetings can take place e.g. twice a year. It is important to focus on different thematic issues at the meetings and address therefor different subgroups. By this approach not every member of the working group has to participate at every meeting.

Furthermore, a good participation can be reached by involving the local policy makers such as city and administration that should also support activities in the DH sector that are concrete

and acknowledged by the stakeholders. It is also evident that the activities are sustainable and not only project related.

8.4 How can the topics be found that are discussed in the working group?

The first workshops can be focused on receiving input from stakeholders regarding needs, barriers and opportunities. To effectively collect ideas at the workshop, the participants can e.g. be contacted by email before and asked on already in the public discussed topics as input for the workshop.

Afterwards the collected ideas should be prioritized and one after the other picked and addressed as central theme at the following meetings.

8.5 How it is possible to profit from the experiences in the other implementing regions?

Although the situation and experiences in the regions are different these can be shared with the other project partners. Some topics can also be developed in cooperation.

Furthermore, experts from the other regions can be invited to speak at one of the webinars or asked to participate at one of the meetings.

8.6 What are the main achievements?

- Creation of a new regional network of stakeholders involved in upgrading DH
- Workshops and training courses on DH upgrading issues
- Profiting from the interaction with the other regions
- Benefiting from the advice from expert partners from abroad
- Political will to support the development of upgrading DH
- Cooperation and discussion between different authorities involved in DH upgrading issues
- Increase of market activities and new projects

9 Annex B: Strategy for a global assessment of DH Networks

The global assessment was split into two parts. The first part is based on a template that can be filled in by the DH system operator, to gain a proper overview about the system and the unknown values, which may be required for a detailed evaluation if the system operates well.

9.1 Global assessment of DH systems

The aim of the global assessment is to analyse the current situation in a district heating system on technical and non-technical (economics, organization, socio-economics, managerial) circumstances.

Therefore, it includes:

- General data sheet template for first data collection on technical and non-technical information on the generation, distribution and use of heat at you in a district heating system
- Interview guideline for interviews with stakeholders at a district heating system, e.g. utility, DH network operator, consumer association.

9.1.1 Introduction to the district heating system

The aim of the introduction is to give an overview of some basic information (e.g. location of the district heating system, responsible partners) as well as some background information (e.g. 'history' of the plant) and information on expectations (e.g. expectation how the district heating system can/ should develop in the near future).

Fill in the introduction ...

9.1.2 General data collection

Assess in the following the current situation of your district heating system regarding technical and non-technical (economics, organization, socio-economics, managerial) issues, distinguishing between generation, distribution and use of heat.

Heat generation

Table 1: Heat generation – Technical

Technical	
Overview	<i>Insert a map with all energy producers (CHP, boilers, etc.) and pumping stations.</i>
Energy carriers and heat generation (installed capacity in $MW_{th/el}$)	<p><i>State the No., age, installed thermal (electric) capacity of each energy source/ power station</i></p> <p><i>Type of source: Combined Heat and Power plant, Boiler, Including excess heat from industries, solar thermal, biomass, biogas, heat pumps, geothermal heat, etc.:</i></p> <p><i>Please add the main used fuel for each source (Coal, oil, gas, biomass, etc.)</i></p> <p><i>State the operation purpose and strategy, e.g. peak load, base load, mid load, heat operated, power operated</i></p> <p>- ...</p> <p>- ...</p>
Performance (kWh_{el} / MWh_{th})	<p><i>State the performance of the heat supply (additional electrical consumption to operate the system in kWh_{el} per generated heat in MWh_{th}) :</i></p> <p>- ...</p>
Heat storage (in m^3 and $in^{\circ}C$)	<p><i>State the No., type (water tank pressurized/non-pressurized, pit storage, borehole storage, etc.), purpose (seasonal, weekly, daily, flatten peak load, etc.), size of the heat storage, min. and max. temperature:</i></p> <p>- ...</p> <p>- ...</p> <p><i>Is there a heat pump to discharge the heat storage (e.g. pit storage) to a lower temperature level?</i></p> <p>- ...</p>
Provision of cold?	<p><input type="checkbox"/> No</p> <p><input type="checkbox"/> Yes, by: ... (e.g. type of chiller, age, capacity, etc.)</p> <p><i>If absorption chillers are used, what are the flow and return temperatures? What kind of (re)cooling system is used (wet, dry, hybrid, adiabatic)?</i></p>

Amount of heat (cold) generated (in MWh/a)	<i>Primary energy supply: ...</i>
Primary energy demand	<i>State the current primary energy demand (Use the calculation method elaborated by OPTIT in Month 3 (Task 4.6)): ...</i>
Primary energy factor	<i>State the primary energy factor of the DH network and the calculation method (if applied in your country): ...</i>
Fuel supply	<i>State the current fuel supply (e.g. tons of locally sourced woodchips, liters/tons of imported oil/coal, etc.): - ...</i>
Share of renewables (in%)	...
GHG emissions (in t CO ₂ -equivalent/a)	...

Table 2: Heat generation – Non-technical (economics, organization, socio-economics, managerial)

Non-technical (economics, organization, socio-economics, managerial)	
Type of company	<i>Utility, public, private, etc. (including the main characterising figures, as No. of employees, annual sales, etc.): ...</i>
Operation	<i>Who specifies how the DH network has to be operated? ...</i>
Maintenance	<i>State the <u>major</u> current regular maintenance activities (equipment repair and overhaul, equipment health monitoring, etc.) and its frequencies (weekly monthly, yearly): ... - ...</i>
Costs for maintenance tasks	<i>State the expenses for relevant maintenance tasks: ...</i>

Heat distribution

Table 3: Heat distribution – Technical

Technical

DH network length (in km)	<i>Insert a map of your DH network and state the length for main pipes and connecting pipes:</i> - ...
Connected load	<i>How high is the simultaneity factor (network heat input divided by the sum of the connected heat load)?</i> - ...
Age of DH network	...
Type of DH network	<i>Describe the DH network (primary, secondary grid, etc.) and its layout (mesh, star, etc. layout of DH network):</i> ...
Quality of DH network	<i>State information on the quality (pre-insulated pipe; channel type; plastic/ steel jacket pipe; etc.):</i> ...
Temperature levels (in°C)	<i>Supply / return pipe for winter / summer operation: ...</i>
Operation Mode	<i>Constant or gliding (ambient temperature driven) operation: ...</i>
Main pipe types/ network characteristics	<ul style="list-style-type: none"> - <i>Dimension: ...</i> - <i>Pressure: ...</i> - <i>Flow: ...</i> - <i>Heat losses in% (state how calculated) ...</i> - <i>Water losses in% (e.g. number of refills/ re-feedings per year: ...</i>
Water quality	<p><i>State the water quality (conductivity in $\mu\text{S}/\text{cm}$; oxygen, etc.):</i> ...</p> <p><i>Are there corrosion problems (inside, outside)?</i> ...</p> <p><i>Are there special times, when the network is shut down for repair reasons?</i> ...</p>
No. of connections	...
DH network pumps	<i>State the No., age, installed capacity, etc. of the installed network pumps:</i> ...
Pump regulation	<i>Without regulation, regulated by pressure difference, regulated by index circuit: ...</i>

	<p>Are there network pumps, operating from different directions into the network?</p> <p>...</p> <p>Do you have any data transmission, like differential pressures, temperatures and flows from the network to a central SCADA system?</p> <p>...</p>
Hydraulics	<p>Does a current hydraulic calculation of the network exist and who is taking care of it?</p> <p>...</p>
Problems	<p>If there are any problems with the network, what kind of problems are these (static or hydraulic problems, others)?</p> <p>...</p>

Table 4: Heat distribution – Non-technical (economics, organization, socio-economics, managerial)

Non-technical (economics, organization, socio-economics, managerial)	
Type of company	<p>Cooperative, utility, etc. (including the main characterising figures, as No. of employees, annual sales, etc.):</p> <p>...</p>
Documentation	<p>Are site maps available for the DH network? Information on road, railway, river crossings, etc.:</p> <p>...</p>
Maintenance	<p>State the current regular maintenance activities (pipe inspection, leakage detection, etc.) and its frequencies (weekly monthly, yearly):</p> <p>- ...</p> <p>- ...</p>
Costs for maintenance tasks	<p>State the expenses for relevant maintenance tasks:</p> <p>...</p>

Heat use

Table 5: Heat use – Technical

Technical	
Annual heat supply (in GWh/a)	Amount of heat sold to the customers: ...
No. of house substations	State the number of house substations: ...

Size of connected customers	<i>State the (average, min. and max.) capacity of the installed heat transfer stations: ...</i>
Temperature levels	<i>State the required temperature level (average, min. and max.) of the different customers (design temperatures for radiators/heating systems): ...</i>
Type of sub-stations	<i>State the average age, type, etc. of the heat transfer stations: ...</i>
Level of digital monitoring	<i>Describe the level of digital monitoring of the connected customers-substations...</i>

Table 6: Heat use – Non-technical (economics, organization, socio-economics, managerial)

Non-technical (economics, organization, socio-economics, managerial)	
No. of customers	...
Type of customers	<i>E.g. Industry, trade and commerce, housing etc.:</i> ...
Heat price (in €/kW and €/kWh)	<i>State the capacity charge €/kW and energy charge €/kW with and without VAT:</i> <ul style="list-style-type: none"> - For private households: ... - For industry: ...
Contracts	<i>State the contract duration of the customers:</i> ...
Redensification	<i>Describe your current activities in connecting additional customers to your network in new/ existing areas of the DH network:</i> ...
Return temperatures	<i>Describe your current activities to lower the return temperatures of the customers:</i> ...

9.2 Interview guideline

Date/ Time/ Place	<p>State the date, time and place of the interview:</p> <p>...</p>
Interview partner	<p>Name and organization of interview partner:</p> <p>...</p>
Stakeholder type and sector	<p>Allocate your interview partner to the following options:</p> <p><input type="checkbox"/> Heat generation: ... (e.g. utility)</p> <p><input type="checkbox"/> Heat distribution: ... (e.g. DH network operator)</p> <p><input type="checkbox"/> Heat use: ... (e.g. consumer association, customer)</p> <p><input type="checkbox"/> Policy</p> <p><input type="checkbox"/> Other: ...</p>
Current technical challenges	<p>Let the interview partner describe technical challenge(s) related to the district heating system. Summarize the findings with about 500 characters. Include in the description when the challenge did occur for the first time and what is the (assumed) reason for it:</p> <p><input type="checkbox"/> Heat generation:</p> <p><input type="checkbox"/> Heat distribution:</p> <p><input type="checkbox"/> Heat use:</p>
Current non-technical challenges	<p>Let the interview partner describe non-technical challenge(s) related to the district heating system. Summarize the findings with about 500 characters. Include in the description when the challenge did occur for the first time and what is the (assumed) reason for it:</p> <p><input type="checkbox"/> Economical:</p> <p><input type="checkbox"/> Organizational:</p> <p><input type="checkbox"/> Socio-economical:</p> <p><input type="checkbox"/> Managerial:</p>
Further questions	<p>State here further questions you have asked and the corresponding answers with maximum 500 characters for each answer:</p> <p>- ...</p>

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