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## On the road to low temperature district heating

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**Abstract.** The roadmap to implementation of low temperature (LT) grid taking into account existing district heating (DH) systems is analysed in the paper. Lessons learned from pilot cases in Albertslund, HojeTaastrup, Kalundborg and Łomża are presented. Also in Albertslund and Hoje Taastrup LTDH grids constituting subgrids of the main (third generation) DH grids, and the last is fed from the DH return-flow. In Kalundborg an independent ultra-LTDH grid is considered to utilize the low temperature surplus heat (around 20°C) as supply for Municipalities located nearby. In Poland the effects of a lower supply temperature in an entire DH grid were investigated. This lower supply temperature was effective on account of the existing DH-grid infrastructure being oversized.

### 1. Introduction

We are living in a period of crucial change (paradigm shift) in energetics, including district heating (DH) systems. Developed and built between 1930 – 1970, 2<sup>nd</sup> Generation (2G) DH (with supply temperature above 100°C and coal as main energy source) has been replaced later by 3G DH using coal, biomass and wastes as primary energy sources and lower supply temperature (80 – 100°C). The 4G DH [1, 2] is knocking at the door (with pilot installations in Denmark [3], England [4], Norway [5], Belgium [1], Finland [6] and Germany [2,7]). The 4G DH with a supply temperature below 70°C enables lower heat losses, integration of renewable heat (solar, geothermal, wastes and biomass sources) and compatibility with cooling networks and smart energy systems. Moreover, 5G DH is being discussed, which integrates heating and cooling, enables demand side response and related thermal energy storage, and wider integration of waste/surplus heat sources [8]. Some new, innovative ideas of integrated district heating and cooling networks are being developed, e.g. Ectogrid™ to be implemented by E.ON Sverige AB [9].

The role of district heating (especially Low Temperature DH - LTDH) in decarbonization of energy systems was discussed in ref. [10, 11]. The LTDH systems allow utilization of surplus heat from industry and waste-to-energy systems, and use of geothermal and solar thermal heat. The technologies converting solid biomass into bio(syn)gas as well as liquid biofuels will also play an important role in future "smart energy systems". Such systems are characterized by a high degree of integration with district heating, cooling, electricity and transport fuel, leading to possible synergies among them.

Nowadays the burning issue is: how to transform existing heat supply systems into 4G (or even 5G) systems? What roadmap to LTDH is possible and most effective (economically and ecologically)? The paper aims at the evaluation (lessons learned) of existing attempts to introduce LTDH in various municipalities. In Albertslund [12], HojeTaastrup or Berlin Adlershof [7] LTDH grids constitute a subgrid of the main (3G DH) grids; in HojeTaastrup the grid is fed from DH return-flow. In Kalundborg an independent ultra-LTDH grid is considered to utilize the low temperature surplus heat



(around 20°C) as supply for nearby located municipalities. In Poland, a different approach was considered due to recent political, economic and technology changes. Widely implemented energy efficiency measures and better insulation technologies result in much lower heat demand and thus an oversized DH grid [13-17]. Therefore, one can consider a temperature decline in DH feed flux. An example of such changes in the Łomża DH grid is analysed.

## 2. Pilot installations

Four versions of 4G implementation roadmap are analysed here, including the largest Danish LTDH installation (560 *modernized* houses in Albertslund) working as a *subgrid*, the LTDH in Hoje Taastrup for *non-refurbished* houses supplied from *return-flow* of 3G DH, a planned *ultra-LTDH* (~20°C) *separate grid* in Kalundborg region and a 3G DH grid with *decreased supply* temperature in Łomża.

### 2.1. Albertslund LTDH project

Albertslund, a 1980's rather poor municipality with high unemployment and social problems, is located in a periphery region of Greater Copenhagen. This partly agro municipality counts 28 000 people living on a land area of 23 km<sup>2</sup>. Nearly half of the housing belongs to the Commune and were built in early 60's and 70's; needs total renovation. In 80's local policy makers decided to develop the plan aiming at regional revitalisation as well as climate and environment protection. Having limited resources (unemployment and social needs) the city administration decided to include citizens into a decision making group, to discover their priorities and make the decision process a bit easier. The „Brugergruppen” (user groups) helped local politicians to find the best solutions for the citizens and environment. Today, Albertslund is known as a living-lab for new eco-solutions, including energy and finance saving heating systems, LED (DOLL) lighting and smart-city solutions. In the years 2006-2015 reduction of CO<sub>2</sub> emission surpassed 25%. New SEAP envisions that by 2025 all space heating and electricity will be produced with zero CO<sub>2</sub> emission- by the introduction of 4G district heating and better use of local energy sources (e.g. wind farms and heat pumps).

Nowadays, the municipality is heated by a DH grid supplied by waste incineration and a CHP biomass combustion system. By 2026 LTDH is going to be implemented across the whole city. Before this, housing must undergo complex refurbishing (first the tenants, then private and industrial houses) and 380 km of worn and ineffective heat distribution pipework must be replaced by a new well insulated grid.

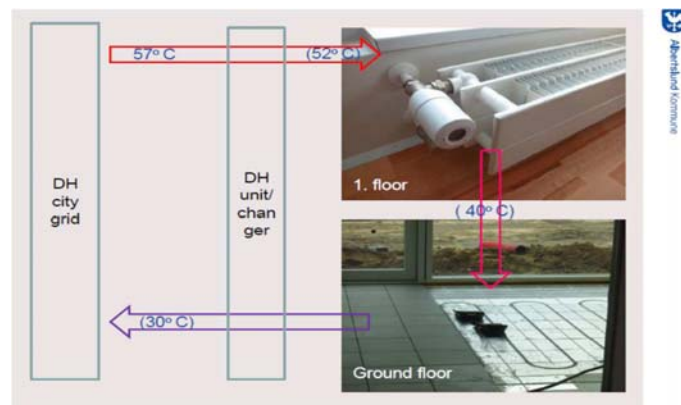


Figure 1. Heating system in Albertslund LTDH housing department, after Oxenvad [12]

The first pilot project, performed at an old and economically weak housing department (560 houses), was finished in 2015. It is the largest LTDH system in DK (and probably EU), representing LTDH implemented for existing buildings after comprehensive refurbishment, which included: roof, wall and basement insulation ( $\lambda = 0.020$  W/m K), floor heating system with additional new type radiator (2 or 3 layer radiators) with blowers. The City supplies LTDH system with temperature 57°C

at the heat exchanger of each house – see Fig. 1. The radiators are fed with water flux at 52 °C and the floor system is subsequently fed with the return flux from radiators at 40 °C. The return flux from houses is at really low temperature  $T = 30$  °C, i.e. the temperature drop in the system equals  $\sim 27$  °C.

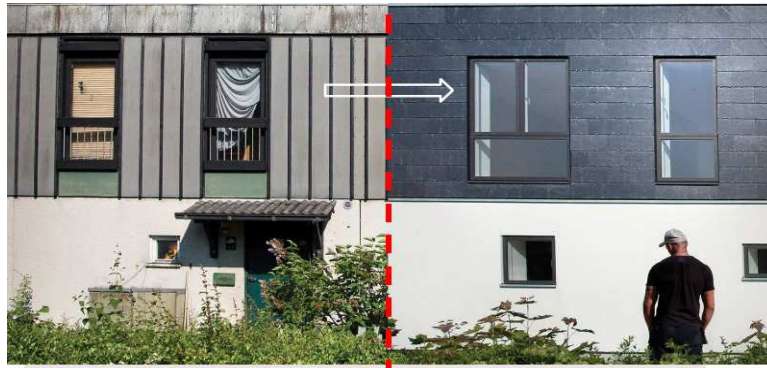


Figure 2. Albertslund renovated houses (right) in contrast to original state-of-art (left), after Oxenvad [12]

The results of the renovation works are presented in Fig. 2. (left side before and right side after renovation). The heat supply and thus its cost decreased about 50% - this enables a credit handling using ESCO model i.e. from savings on the heating bill.

### 2.2 Høje Taastrup municipality suburb of Copenhagen

Høje Taastrup municipality (with 48,500 inhabitants) is known for its green transformation agenda. By 2050 the region is aiming to be 100% carbon free. The municipality is composed of small housing areas, with detached houses, terraced houses and some multifamily houses, most built between 1960 and 1990. About 50% of the houses are connected to the heat grid, the rest employs gas and oil boilers. The city aims to provide LTDH and a heat pump utilizing local surplus heat (from industry).

One of the issues to be tested is LTDH in non-refurbished buildings. It is assumed that it is not feasible (technically and economically) that all buildings in DK will be refurbished to high energy standards in the timeframe of 2035 - 2050, when LTDH is going to be introduced. Is it then possible to connect a housing district to LTDH, before the all houses are renovated to low heat standards?

The Høje Taastrup Fjernvarme a.m.b.a. developed a pilot LTDH in the district called Sønderby - built in 1997-98, using return flux from DH in neighbouring area as the main supply ('cold supply') for the system. The network includes 75 detached houses (110-212 m<sup>2</sup> living area) with under-floor heating; the total heated area - 11,230 m<sup>2</sup>. When the return-flux temperature is not sufficient for the LTDH-grid, a portion of hot water from the 'hot supply' (3G DH grid) is added in a mixing shunt. The "cold supply" provide heat in the range of 30-67°C (48°C in average) - highest during summer. The "hot supply" provide heat in the range of 65-107°C (80°C in average) - lowest during summer. The measurements showed that the "cold supply" has covered 81% of the total supply of LTDH system.

Before the LTDH was introduced the distribution pipelines – pair of single pipes were replaced as the annual heat losses of the grid accounted for about 38-44% of the heat delivered from the central heat exchanger. The new TwinPipe system, series 2, size 76 and smaller with Logstors alarm-system X4, which provides a precise identification of leakage location, was applied. In all main (street) grid "conti-produced" twin steel pipes insulation class/series 2 with heat conductivity  $\lambda = 0.023$  W/(mK) were used. To connect individual houses to the LTDH grid, flexible twin alupex (aluflex) pipes in insulation class/series 3 with heat conductivity  $\lambda = 0.022$  W/(mK) were used.

In each house new substations, an instantaneous water heater type, designed for a capacity of 32.3 kW (according to Danish standards) were installed. Due to regulation on safety in relation to bacteria the water content in each domestic hot water supply line, including the volume in the secondary side of the heat exchanger, is limited to 3 litres. According to design, district heating supply temperature is 50°C for domestic hot water allowing water temperature above 45°C.

It was found that after investment heat losses decreased from around 40 to ~13%. Measured mean supply and return temperatures of the LTDH network were 55°C and 40°C, respectively (which corresponds to design values 55°C and 27-30°C). At consumer substations, the temperatures were ~53 and 38°C, respectively (design 50 and 25°C). The temperature drop 15°C instead of 25°C (as designed) highlights some problems which should be considered in future projects. It was found that LTDH is quite sensitive to consumer habits (the bad ones - to large consumption). Finally, it was proved that LTDH can be applied in existing **non-refurbished** housing areas.

### 2.3 Ultra-LTDH project in Kalundborg region

Motivation for development of an ultra-LTDH grid was related to a substantial amount of surplus heat in a densely populated, industrial region of Kalundborg. The considered problem was: Is it feasible and how to transfer low temperature surplus-heat for long distances in an economically viable way?

The software developed in Kalundborg municipality considers different scenarios: insulated transmission, uninsulated transmission, general and individual heat pumps as well as an alternative case i.e. biomass boiler – see Fig. 3. The model is based on thermodynamic calculations and actual costs for grid components. Exemplary result of economy calculation, for long distance (20 km), low temperature LTDH (~300 K) with central heat pump, 19 km uninsulated transmission using PEX pipes to central heat pump, later insulated transmission (1 km) using ISO pipe at temperature 75°C, showed that the payback period under Danish conditions was around 12 years.

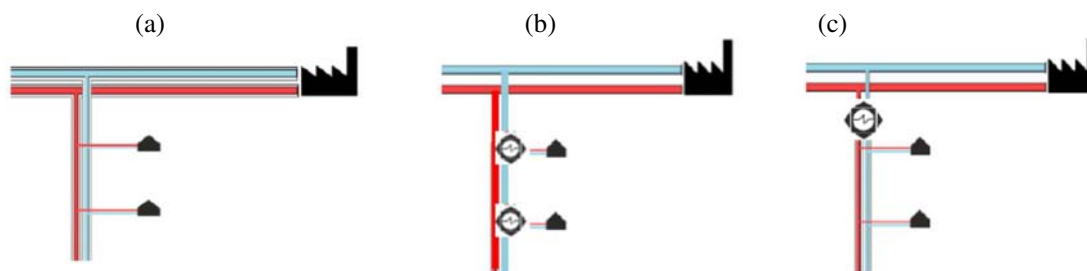


Figure 3. The considered options: (a) insulated transmission, (b) uninsulated transmission line to the village and general heat pump (after Marhauer-Nimb D., Proc. Energy Efficient Cities Conf. 2018 Gdynia, [https://www.imp.gda.pl/ee\\_cities/en/prezentacje.pdf](https://www.imp.gda.pl/ee_cities/en/prezentacje.pdf))

### 2.4 On the road to LTDH in Łomża

Buildings after thermal-upgrading often do not reach assumed effects related to drop of heat intensity and increase of energy efficiency. However, the proper insulation of a building, implementation of thermostatic valves, weather regulators, etc. potentially enable decrease of heat demand and exploitation costs.

Analysis of 700 heating systems and conditions of their operation in buildings before and after thermal modernization [13-16] shows that thermal modernization alone (without proper regulation of central heating installation and substations taking into account significantly reduced actual heat demand) will not bring the awaited energetic, ecologic and economic effects. It was found that in some cases it may even lead to an increased (up to 10%) heat consumption. In contrast, an implementation in renovated building a proper thermal-hydraulic regulation of existing central heating installation and substations as well as a decrease in the supply temperature in DHS can result in lower heat losses and cost of the supplied heat (10-20%) and real decrease of heat consumption in the buildings (~30%).

Presently, the most important task in the field of district heating in Poland is the gradual transformation of existing DH systems into modern 3G grids with supply temperature below 100°C. This is possible and needed taking into account oversized radiators, heat exchangers and the grid after huge work being done in respect of thermal modernization of buildings. Such work has been

undertaken in the 2017/2018 heating season in a DH system in Łomża (east Poland) as part of a project aiming at increased actual energy efficiency [17].

On the basis of collected annual data (i.e. temperatures, pressures, water flow rates and weather conditions), operational analysis using computer simulation for district heating network was performed. The result of the analysis allows to verify present “heating curve”, and create the most efficient one [13], [15], [16]. The “heating curve” has to be created individually profiled for a particular district heating system and mainly depends on technical condition, types and sizes of existing heat exchangers in the system, and verification of real heat demand and weather conditions.

In the first stage of implementation the nominal supply temperature in DHS was decreased from 121°C to initially possible level 109,8°C;. This was possible due to oversized heat grids as well as heat exchangers in buildings (on average above 2 times). Finally it was found that:

- Real heat losses in the DH grid decreased about 14% if related to mean heat losses registered for two previous heating seasons.
- During the whole heating season hydraulic stability of the DH system was improved significantly. For example before the implementation (in 2015/2016 heating season) total flux of water in grid varied in the range 250 m<sup>3</sup>/h and 1322 m<sup>3</sup>/h (mean value was 953 m<sup>3</sup>/h), i.e. it varied by a factor of over 5 during the season. After the first stage of implementation (in season 2017/2018) total water flux in the heat grid varied between 912 m<sup>3</sup>/h and 1501 m<sup>3</sup>/h (mean value 1229m<sup>3</sup>/h), i.e. (total flux changes only 64% during whole season).
- The cold and warm water-flux mixing-systems work under much better seasonal conditions; a stable grid-water flux through boilers make it easier to keep lower supply temperature during the heating season and fulfil requirement of the new individually profiled heating curve. In the 2017/2018 heating season deviation from the value of supply temperature required by new heating curve was halved.

Moreover, the developed and fully verified thermo-hydraulic model of the existing DH system in the city constitutes a good basis for planning further modernisation activities, which aim at implementation of 4G DH (during next 3 years) with nominal supply temperature (in whole grid) below 100°C.

### 3. Conclusions

LTDH grid is a sustainable solution for heat supply systems using various surplus heat sources. The presented pilot projects have shown that the 4G roadmap can be implemented even for existing (**non-refurbished**) buildings, especially those already equipped with underfloor heating as their space heating system.

The results show that it is possible to supply the customers with a supply temperature of ~50°C and satisfy both the space-heating requirements and biologically safe provision of domestic hot water. It is possible to solve Legionella problem by decrease of heated-water volume (below 3 l). The distribution-network heat-loss has been confirmed as 13-14% of the total heat supply to the LTDH system. Significant energy savings are possible by application of LTDH - in some cases even above 30% - so, energy efficiency targets can be met.

The improved economy (achieving a 10-12 years payback period) was found, for investment in long distance (20 km) ultra-LTDH (~300 K, below 30°C) with central heat pump; 19 km of cheap uninsulated transmission PEX pipeline to central heat pump, later insulated transmission (1 km) using ISO pipe working at temperature of ~75°C.

It was found that in Poland it is possible to gradually transform existing district heating systems into grids with supply temperature below 100°C. This is possible and takes advantage of oversized grid resulting from the huge work being done in respect of thermal modernization of most buildings. Properly done grid modernization and implementation of “individually profiled rational quantitative and qualitative seasonal regulations” in existing DHS can result in a reduction of heat losses and cost of the supplied heat (10-20%) and real decrease of heat consumption in the buildings (~30%). Besides, the grid hydraulic stability and working condition of mixing systems are improved significantly.

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