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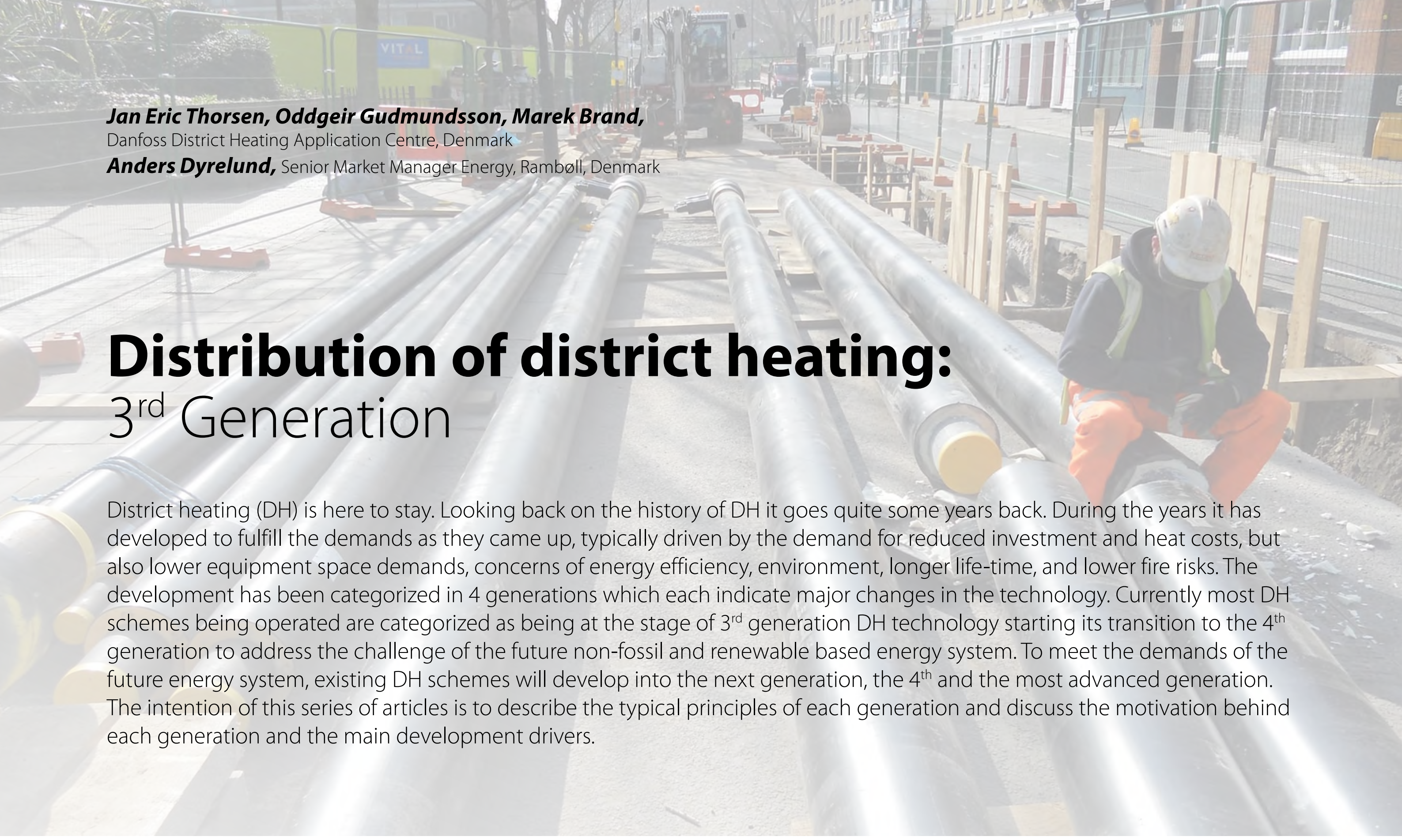

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Distribution of district heating:
3rd Generation

District heating (DH) is here to stay. Looking back on the history of DH it goes quite some years back. During the years it has developed to fulfill the demands as they came up, typically driven by the demand for reduced investment and heat costs, but also lower equipment space demands, concerns of energy efficiency, environment, longer life-time, and lower fire risks. The development has been categorized in 4 generations which each indicate major changes in the technology. Currently most DH schemes being operated are categorized as being at the stage of 3rd generation DH technology starting its transition to the 4th generation to address the challenge of the future non-fossil and renewable based energy system. To meet the demands of the future energy system, existing DH schemes will develop into the next generation, the 4th and the most advanced generation. The intention of this series of articles is to describe the typical principles of each generation and discuss the motivation behind each generation and the main development drivers.

The main characteristic of the 3rd generation DH system is the material and labor lean components applied combined with general lower temperatures. The components consists of pre insulated pipes buried directly into the ground and fixed without expansion loops, prefabricated compact substations, the use of compact brazed stainless steel plate heat exchangers and the use of material lean components such as combination valves. The 3rd generation district heating is also referred to as the "Scandinavian" district heating technology, since the development and commercialization was mainly done by suppliers based in Scandinavia mainly in the period from 1980 to 2010. Also the description "Prefabricated" is a used term for this area. Pressurized water is used as heat carrier, typically designed at temperatures below 110 °C but operated at temperatures typically below 100 °C.

The 3rd generation district heating was introduced in the 1970s and has been applied in almost all new schemes and renovation projects from approximately the year 1980. The motivation for this generation was the increased focus on lower construction cost and energy efficiency, e.g. triggered by the oil crises in the 70s leading to high fuel prizes. Related factors were the security of supply aspect, where alternatives to oil found their way into the energy system. This included e.g. biomass and waste incineration. As a direct consequence of the oil crisis, CHP in Denmark became mandatory and was applied in many other countries as well. This boosted the deployment of DH heavily in this period.

The development into the 3rd generation district heating concept lead to a number of benefits compared to the 2nd generation, for example:

Reducing the operation costs by:

- Reducing the temperatu re levels, leading to savings in thermal distribution losses and better heat plant efficiencies.
- The general lower temperatures opened the opportunity for other low cost and/or renewable heat sources.
- Increasing the thermal resistance of the insulation, leading to savings in thermal distribution losses.
- Pre-insulated pipes, leading to long lifetime of the pipes and reduced installation time.
- Leakage detection systems for the pipes.
- Use of energy meters to bill according to real consumption.
- Components and systems of higher quality and efficiency.
- Control and monitoring systems to allow optimal operation and load dispatch of larger systems

Reducing the investment costs by:

- Pre-insulated pipes buried direct into the ground without expansion joints.
- Pre-fabricated material lean substations.
- Improved DH pipe construction methods inspired by e.g. the gas-pipe technology.
- No-dig methods
- Curved pipes
- Prefabricated joints
- More cost effective and larger unpressurized heat storage tanks

Pipes:

The 3rd generation pipes consist of typically steel media pipes which are pre-insulated at the factory with cellular polyurethane insulation bonded to the media pipe and the outer plastic casing. The media pipe can also be made by cupper or PEX. To prevent diffusion of humidity from the surrounding soil into the insulation material, pipes can be equipped with a diffusion barrier of aluminum foil. This maintains the thermal insulation properties over time. The concept of twin pipes was introduced as well. Twin pipes consist of a flow and return pipe within the same insulation and outer casing, see figure 1. This concept leads to savings in network investment and installation costs and has significantly reduced heat loss compared to two separate pipelines. For smaller pipe dimensions, lower pressure rating and lower operational temperatures PEX pipes became available. The advantage achieved with the PEX pipes are their cost efficiency and flexibility which effectively reduces installation costs. Thermal elongations are absorbed directly by the surrounding soil or by cushions placed at relevant locations. The flexibility of the pipes itself is utilized by bending them, enhanced by geometrical based flexibility like L, U or Z bends. Compensators are rarely applied.

Compared to the pipe concept of the previous generation where the pipes were placed in ducts and insulated at site, the 3rd generation pipe concept means reduced number of components required, less excavation, welding and mechanical labor needed and reduced heat loss through better insulation.

Substations:

Compared to the 2nd generation principles, where substations were typically build on site, the 3rd generation substations are prefabricated in industrialized processes where materials and labor is reduced. Focus is on energy efficiency regarding the heat exchanger, the control components, the insulation of the substations and also the physical dimensions or compactness. The heat exchangers are typically made by cupper brazed stainless steel plates and are very compact. They have a high heat transfer rate pr. weight unit and a long life time. The general trend for heat

FIGURE 1: Pre insulated pipes laid direct into the ground

FIGURE 2: Prefabricated curved pipes

FIGURE 3: Heat storage, 2 x 24,000 m³ up to 120°C and 10bar pressure

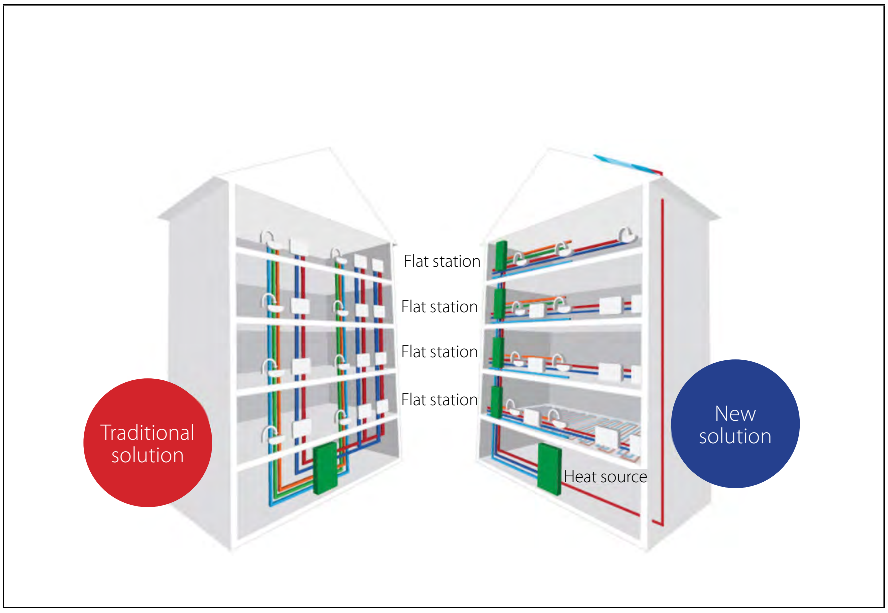

***FIGURE 5:** Traditional solution and flat station solution. Heat source can be district heating.*

exchanger dimensioning was, and still is, reduced temperature differences, say difference from primary to secondary side, with the aim to reduce the operating temperatures and thus reduce thermal distribution losses in the network. Where relevant, the control valves can be of "combination valves" types. This means three separate valves built into one valve, for example control valve, differential pressure controller and flow controller.

The benefits of the combination valves are reduced cost, through material savings, reduced hydraulic losses and reduced installation time, one valve instead of many. Insulation of the substations became a basic demand. Depending on different parameters the substation is either insulated at the factory or on-site, the deciding parameters can be risk of transport damage and the need to have access e.g. in relation to connecting the substation. The electronic controller typically has functions to reduce the energy consumption, like weather compensation, setback periods, flow and or return temperature limitation.

As alternative to prepare the domestic hot water centrally for a multi-family house, the concept of flat stations emerged. The concept is to have a substation in each apartment, where fresh domestic hot water is prepared for each flat at the time of usage. Hereby only a small volume of domestic hot water is hold up in the pipes, leading to a higher level of hygiene e.g. in relation to bacteria growth, such as the legionella bacteria's. This concept allowed metering energy consumption by only one meter covering heating and domestic hot water on an individual basis. As can be seen from Figure 3 the concept reduces the number of distribution pipes in the building from 5 to 3 compared to the traditional distribution system.

A major benefit of the flat station concept is that it prepares multi-apartment buildings for operation at low district heating supply temperatures, due to the reduced risk of bacteria's in the domestic hot water system.

The system can be compared with district heating supplied to one-family house districts. The difference is that the district heating pipes are not horizontal pipes in the soil, but vertical and less costly pipes in the apartment buildings.

A major advantage is that the building owner or the association of home owners doesn't have to operate the hot tap water system and that it will be much simpler and more accurate to share fixed and variable costs among the users. It opens even for the opportunity for the DH company to deliver heat directly to each apartment, either via own pipes or via pipes established by the building owner, depending on the local legal requirements.

The flat station concept is a good option when renovating older buildings, leading to energy savings due to individual decentralized control options for the inhabitants.

Energy Sources:

Besides traditionally CHP plants at high temperatures or waste incinerators, which traditionally has been the backbone of the energy supply, the reduced temperatures, compared to the 2nd generation, opened the possibilities of increasing the efficiency of the production plants and utilizing renewable heat sources. This includes waste incineration and biomass plants with flue gas condensation, large scale solar thermal with e.g. seasonal storage, geothermal and excess heat from commercial and industry side. In some places heat pump plants are installed to enhance the temperature levels of the low temperature heat sources and use surplus electricity at low prices. The extent of renewable heat source utilization varies from country to country.

Meters:

To be able to allocate the costs of the actual consumed heat towards the end consumers, building level or individual energy meters are applied. Nowadays the meters are remotely read at least once pr. year, with a tendency to more often. Many companies register both energy and flow consumption in order to calculate the average cooling of the district heating water to be used as a parameter for the tariff, to give incentives for better cooling. Newer

***FIGURE 4:** Compact insulated prefabricated substations. One type with cover and one type without cower*

meters also register the average flow weighted return temperature which is an even better parameter for the tariff to give an incentive to reduce the return temperature.

Benefits

The main benefit of the 3rd generation DH system compared to the 2nd generation DH system is the increased energy efficiency due to lower operating temperatures and the reduced investment and operation costs due to more pre-fabrication, pre-assembly and pre-insulation at the factory. Also the fuel mix has been altered by feeding in greener and renewable sources, resulting in lower emissions. The 3rd generation has made a huge contribution, and still has enormous potential, towards fulfilling the political energy goals.

The next coming generation district heating (4th generation)

The future energy system has to be secure, reliable, flexible, fossil free and sustainable and this at the lowest possible cost. Without doubt district heating has a central role to play. In the future a higher pressure will be on utilizing renewable low grade heat sources to a larger extend. A common denominator for renewable low grade heat sources is that they tend to be difficult to access on a building level, either due to location or required investments. District heating is the key technology to overcome these issues and deliver the heat to the place of usage at high efficiency. Although district heating is the key for increased share of renewables in the energy mix it requires the district heating system to develop further. In addition to the wish of utilizing low temperature renewable heat source the building codes are being tightened, which effectively reduces the heat demand and temperature requirements of the building stock.

To overcome the issues with both utilizing the low temperature renewable heat sources and the reduced heat demand of building the district heating networks need to be able to operate at even lower supply temperatures then commonly done today. The reduced supply temperature not only increases the efficiency of the system but also increases the flexibility of the district heating system towards the energy system as a hole.

The concept of district heating has to be seen as an integrated part of the future smart energy system, including also district cooling, electricity and gas grids. The technology of district heating must develop and be versatile to effectively position district heating into the future energy system. In particular district heating has to develop in symbiosis with district cooling in order to benefit from the synergies between these two twins. One of the obvious new trends is to use these synergies, e.g.:

- Co-generation of heating and cooling in electric heat pumps supplying heat to low temperature district heating grids at e.g. 60°C.
- Combined use of cold and hot water aquifer storage seasonal (ATES)
- Combined use of heating and cooling installations in buildings (floor tubes and ventilation coils)
- Providing a total solution to the building owner
- Improving the flexibility and storage capacity of the thermal systems to integrate fluctuating and low quality renewable energy sources in a cost effective way (virtual battery).

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References

- Lund, H. et. al. (2014) 4th Generation District Heating (4GDH). Integrating Smart Thermal Grids into Future Sustainable Energy Systems. Energy 68(2014) 1-11.
- Frederiksen, S. Werner, S. District Heating and Cooling , Studentlitteratur, Lund 2013.
- Thorsen, J. E. et. al. (2012) Impact of lowering dT for heat exchangers used in district heating systems. The 13th International Symposium on District Heating and Cooling, Copenhagen, DENMARK
- Thorsen, J.E. (2010) Analysis on Flat Station Concept. The 12th International Symposium on District Heating and Cooling, Tallinn, Estonia
- Christian Holm Christiansen, C. H. et. al. (2010) Results and Experiences From a 2-year Study With Measurements on a New Low-Temperature District Heating System for Low-Energy Buildings. The 13th International Symposium on District Heating and Cooling, Copenhagen, DENMARK
- Kristjansson, H. (2008) Distribution systems in block of flats. The 11th International Symposium on District Heating and Cooling, Reykjavik, ICELAND

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