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## Challenges in Smart Low-Temperature District Heating Development

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### Abstract

Previous research and development shows that low temperature district heating (LTDH) system is economic feasible for low energy buildings and buildings at sparse areas. Coupling with reduced network temperature and well-designed district heating (DH) networks, LTDH can reduce network heat loss by up to 75% comparing with the current medium temperature district heating system. Further system efficiency improvement can be achieved through a holistic approach which includes measures such as reduced system design margin, enhanced demand side management and improved operation of decentralized heat generations. The realization of such efficiency improvement measures will increase the demand for well functioned monitoring, communication, control and decision support tools and services to coordinate each component in the DH system.

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### 1. Current Status of Low-Temperature District Heating Development

The evolution of district heating (DH) has gone through three generations which are characterized by the type of transport media and the network temperature levels. Up until now, the LTDH is emerging as the 4<sup>th</sup> generation system to replace the existing DH system. Comparing with the current DH system, the LTDH reduces the network supply temperature down to consumer required level. This bring the advantages as reduced network heat loss, improved quality match between heating supply and heating demand, improved power to heat ratio in the CHP plant, and increased utilization of renewable energy and waste heat.

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The LTDH concept was initially brought to ensure DH economical superior than local heat generations when supply DH to low energy buildings or buildings at sparse areas [1]. To reduce the network heat loss, the network supply temperature is reduced from 80°C to 55°C. Advanced pre-insulated twin pipes are applied to minimize the network heat loss [2]. To deal with the reduced network supply temperature, high efficient heat exchanger is used for the instantaneous heat exchanger unit, and the conventional storage tank unit is modified by moving the storage tank to the primary side to avoid the risk of Legionella [3]. It demonstrated that, LTDH coupling with reduced network temperature and well-designed DH network can reduce network heat loss by up to 75% comparing with the current system. This makes DH economically competitive comparing with local heat generation units when the building space heating (SH) demand decreased by a factor 3-4 [4].

The arguments to supply LTDH to existing buildings with high SH demand lies in many factors: the original design capacity of in-house heating installations, the redundancy of DH pipelines, the degree of building renovation, and the possibility for flexible network operation [5]. It shows that it is feasible to supply LTDH to existing buildings through a combined strategy with necessary building refurbishment and raise the network supply temperature temporally during very cold winter period. Additional more development and research activities in LTDH have been reported in the IEA DHC project [6].

## **2. Challenges to Realize Smart LTDH**

LTDH is expected as one of the enablers in the transition to eco/ low-carbon society. The transition to the new generation system is not merely lowering down the network temperature, but a paradigm shift to increase energy efficiency, reduce environmental impact, optimize resource and material utilization, augment the socio-economic benefit, and improve citizen's quality of life. Further system efficiency improvement can be identified through a holistic approach to enhance the communications between heat generation, distribution and utilization. The future LTDH supply will become 'smarter' through well functioned real-time monitoring, control equipment and decision support tools to coordinate each component in the DH system to improve the overall system efficiency, reduce capital investment and keep consumer comfort.

### **2.1 The Reduction of System Design Margin**

Traditionally, the DH system is designed based on experience with large safety margin. This reflects in both over-dimensioned equipment and high network supply temperature. The system designed in this way is more reliable and can tolerate malfunctioned individual components and occasions at extreme situations (for example, many consumers use tapping water at the same time).

Comparing with traditional system, LTDH tends to reduce the system design margin in order to reduce the heat losses and investment costs. The design of distribution networks and building installations should be more accurate and should reflect the best available knowledge accumulated from pioneering demonstration projects and model based design and optimization practices. Examples for such design practices may include applying more realistic simultaneous factor to reduce the dimension of distribution network [4], installing booster pumps at street level [7], and reducing storage tank capacities. In addition, the network temperature level can be further reduced with ultra-low supply temperature around 30-40°C and then boosted at the end user with micro-heat pump units [8].

### **2.2 The Demand Side Management**

Due to the future large share of renewable energy in the total energy supply and the inherent capital intensive characteristic, the planning of renewable heat generation technologies and capacities should be calibrated with building energy conservation strategies. Through extensive building renovation and Demand Side Management (DSM), the consumers' heating demand can be met with smaller installed capacity thus save the capital investment and improve the partial load operation.

In the building heating supply, the aim of DSM is to plan, monitor and operate individual consumer use of energy to produce a favorable effect on utility heat production profile with respect to load shape, time pattern and peak load. Effective DSM can be enabled to use the building thermal mass. DSM can be applied at different levels. For individual buildings, the DSM is to minimize the utility cost during a billing period with optimal zone set-point temperatures [9]. For a cluster of buildings with different thermal load profiles, DSM can best use the building mix to achieve least thermal load fluctuations [10]. In DH supplied residential building areas, DSM can achieve significant peak load reduction and energy saving through night set back and preheat the building with fine-tuned preheating temperature control curves [11]. When supply LTDH to radiators in existing buildings under a temperature compensate curve, peak flow rate occurs during moderate SH load period [12]. DSM for LTDH operation will consider not only to shift peak SH load, but also to shave the peak flow rate to avoid the network maximum pressure exceed the design limit. The effectiveness of DSM depends on both the construction materials and the insulation levels [13]. Therefore, the effect of DSM should also be considered in building renovation which is an essential process to realize large scale LTDH implementation.

### 2.3 The Decentralized Heat Generation

The development of DH will move from current hierarchical and fossil fuel dominated large scale structure toward future decentralized, multiple renewable and waste heat sources dominated small structure. Due to the intermittent nature of renewable energy generation and the distinct load pattern for different types of waste heat sources, the heat provided for the LTDH system may often exhibit variation discordant to the energy use at the end users. Thermal storage can be considered to shave the peak load demand and balance the discrepancy between supply and demand in both short-term and long-term basis. Meanwhile, the current unidirectional heat supply structure may need to adapt bi-directional heat supply due to prosumers in the network who have the capacity to produce surplus heat from building installed solar collector, heat pump, micro-CHP and individual thermal storage.

### 3. Discussion and Conclusion

To further improve the LTDH system efficiency, the traditional experience based system design approach should be replaced with knowledge based decision with the best available methods to reduce the system design redundancy; the amount of heat generated for LTDH should be evaluated in short term to satisfy different heating demand in accordance to the available renewable/waste heat sources, the thermal storage capacity, the network dynamic characteristic and the capability of DSM from the end user. The future LTDH requires real-time information exchange infrastructure that supports the control operations and interactions between control centers and individual sub-systems.

In this study, we intend to identify the challenges for further LTDH development with the aim toward more efficient and intelligent Smart LTDH (SLTDH). Similar to smart grid, SLTDH with the support of a range of novel applications, hardware components, devices and services, will not only enhance the efficiency of DH but also sustain more eco lifestyle of consumers. The goals for SLTDH are:

- Coordinate the demand from the substations in the network to avoid shortage of heat supply and maintain consumer's thermal comfort in the situation that the system design margins are greatly reduced.
- Supervise the malfunctioned substation and set-point errors and other network component to ensure sufficient cooling of DH water.
- Implement supply-side driven operation strategies with coordinating building DSM and network dynamic characteristics to optimize the heat production and heat storage.
- Interface with other energy supply as electricity from smart grid.

One of feasible solutions to achieve SLTDH could be Agent Based approach. In recent years, there has an increasing use for multi-agent frameworks to model complex environments in the field of distributed

energy generation [14], building energy [15], as well as in DH system [16]. Agent based models use a class of computational models includes physical or virtual entities to intelligently interact in the built environment. It is suitable for intelligent DH system control and management due to the inherent modular, decentralized changeable, ill-structured, and complex characteristics [17]. The realization of such application can be coupled with cloud and ubiquitous computing enabled interactions between novel systems and users [18].

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