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Low temperature district heating in Austria: Energetic, ecologic and economic comparison of four case studies

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ABSTRACT

Feasibility of district heating networks for areas with low heat demand of passive and low energy houses implies the development of innovative concepts for the production, storage, distribution and supply of thermal energy. Low supply temperatures enables the use of heat from renewable and alternative sources, currently been neglected due to the usually high supply temperatures used in conventional district heating systems. Further on, low network temperatures are supporting the reduction of operational and investment costs.

The paper describes the development of economically and ecologically optimized concepts for low temperature district heating networks using four representative case studies in Austria: Aktivpark Güssing, Seestadt Aspern, Winklweg Siedlung and Hummel Kaserne. The four case studies offered the possibility to investigate different supply and demand connection schemes and consequently deriving optimized scenarios taking into account local framework conditions, such as consumption and production settings and the related control strategies. The scenarios analysis is performed considering both economic and ecological issues.

The results of the study show that the availability and economic conditions of low temperature heat sources is a key factor for facilitating LTDH networks. In rural areas, lower heat losses due to lower network temperatures are beneficiary for the LTDH network performance.

1. Introduction

The idea of DH (district heat) is based on moving heat from available heat sources to areas where it is needed. Due to possible short distances, the benefits of district heating are primarily evident in urban regions with a high energy density. Within Europe about 73% of the people are living in cities. By 2050 it is expected that the proportion rises to more than 80% [1]. The proportion of district heating in the European heating market in 2010 was around 12% and is expected to increase by 2020 to around 20%. Currently there are more than 5.000 networks spread all over the continent [2]. District heating was introduced in Europe in the early twentieth century. This shows that district heating is not a new technology and it still has an important role to play in the current and future energy system [3].

In the beginning the so called 1st generation of district heating network was introduced using steam as a heat carrier. These systems were first established in the US in the late 19th century and are still used in the old parts of the district heating systems in New York and Paris. In other parts of Europe and the US these systems were replaced by the 2nd generation of district heating, which uses pressurised hot water with supply temperatures over 100 °C as a heat carrier. Many of these systems are still in operation motivated by customer comfort and the opportunity to achieve fuel savings by utilising CHP plants [4]. Space heating in traditional residential buildings has generally been ensured by heat transfer from radiators at about 80 °C supply temperature (maximum secondary side temperature at minimum outside temperature). Therefore district heating networks with lower supply temperatures were established in the market in the 1970s. This so called 3rd generation of

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district heating systems are using pressurised hot water as a heat carrier, but the temperature of the supply line is reduced below 100 °C. Considering gradients of the heat exchanger and to ensure a certain transport capacity, supply temperatures of about 90 °C are needed in these networks. As a result, the distribution losses in these district heating systems are usually in the range of 10–30%. High temperature sustaining materials, such as steel must be used for the piping and only high temperature sources, most of them based on combustion processes can be integrated. However, current building energy performance improvement (both for new build and retrofitting of building stock) contributes to a decreasing district heat demand, which leads to an increase of the relative distribution losses and a decrease of the overall cost effectiveness of district heating networks [5].

One important possibility to counteract this trend consists in a further reduction of heat supply temperatures. This so called 4th generation of district heating will lead to a significate increase of efficiency of district heating systems due to reduction of heat losses, possible integration of cost efficient renewable energy technologies, such as ambient heat via HP (heat pumps) and waste heat from industrial production processes supporting the reduction of operational cost and additionally investment costs [4]. Besides this, also the efficiency of conventional production units like some types of combined heat and power plants can be increased, see e.g. Ref. [6]. Another advantage of lower system temperatures is the possibility of using cheaper materials for pipes (e.g. plastic pipes) and other components like pumps, valves and control devices.

Whereas lower supply temperatures are sufficient to gain comfortable room temperatures in buildings with suitable heating systems (e.g. floor heating, concrete core activation) [7–10], including refurbished buildings [11], a major challenge is the hygienic preparation of DHW (domestic hot water) if supply temperatures drop below a certain value. To avoid the origin and the proliferation of legionella in a centralized DHW system, minimum temperatures must be guaranteed (e.g. at least 60 °C in Austria [12]). In Ref. [13] two types of substations are analysed for Danish conditions. To enable the 4th generation of district heating in different regions with diverse framework conditions, new options on the supply and the consumer side need to be developed. Therefore, an integrated methodology for the development of LTDH (low temperature district heat) supply concepts was conceived and will be presented in this paper.

This study presents optimal solutions of low temperature district heating micro-grids for four representative regions in Austria with regard to the energetic, ecologic and economic performance. Further it delivers among other results a methodology that supports energy players, such as district heating operators and/or developers with a sound methodology and some exemplary innovative concepts replicable in various regions in Austria bearing in mind the boundary conditions of the case study.

2. Methodology

In this paper the following methodology is developed and the steps are presented: 1) designing general low temperature district heating network hydraulic connections for the supply and the demand side (including options for cascading and different DHW preparation principles); 2) based on project workshops, on the case study specific boundary conditions (available energy sources, network design, demand characteristics) as well as on domestic hot water regulation, possible supply and demand connections are selected for different low temperature DH scenarios in each case study; 3) the dynamic response of the thermo-hydraulic behaviour of the LTDH networks is analysed with numerical models providing as results the energetic and ecological KPI (key performance indicators); 4) based on the results from 3) the economic assessment of different scenarios is performed delivering the targeted KPIs namely the ecological, economic and energetic performances; 5) as last step the identification of business models supports the ecological and/or energetic most promising solutions. A graphical representation of the methodology developed is presented in Fig. 1. The detailed description of the steps is provided in the following sections.

2.1. Supply and demand connections

Low temperature district heating networks require optimal connections from the heat plants (and/or other heat sources) to the grid and from the grid to the customers. Within the framework of the Austrian national research funded project “NextGenerationHeat” (FFG-No. 834582) a number of hydraulic demand side connections (as described in Ref. [14]) as well as different supply connections (reported later in the description of the case studies) have been developed.

2.2. Energetic and ecological evaluation

The dynamic thermo-hydraulic behaviour of LTDH networks is carried out with numerical models of the partially simplified and/or aggregated DH systems of the case studies developed in Modelica/Dymola [15,16], based on models of the Modelica Fluid library [17], Buildings library [18] and on the DisHeatLib [19] developed at the Austrian Institute of Technology. Those libraries include models of producer units, hydraulic schemes of substations, building models and preconfigured pipe models. Based on the simulation results, energetic (primary energy consumption) and ecological indicators (CO_2-emissions) for the different scenarios were calculated.

Validation of key components and comparable settings of DH networks have been performed for building models [20,21], substation models [22], pipeline models ([17,23]) and network aggregation method [24]. A detailed error propagation methodology and commonly recognised test cases for validation of dynamic district heating network simulation environments do not exist in the scientific community and therefore have not been performed. However, a common test case standard for Modelica models is going to be developed within the framework of the IEA EBC Annex 60 [25].

2.3. Economic evaluation

The heat production costs were calculated according to the methodology described in Ref. [26]. Data and information concerning prices and operational costs were identified with help of workshops with district heating providers, component manufacturers and funding agencies. Additionally a market research including commercial price catalogues and corresponding literature was carried out.

The annual costs were specified as annual investment costs, costs of operation and energy costs. The investment costs include the initial investment costs for the district heating plant and the pipe network as well as the replacement investments. The operating costs contain the costs independent from energy demand (e.g. maintenance). The energy costs include the costs for the electricity demand of the heat pump or direct electric heater and cost for heat from the district heating network – for the later, a lower tariff was assumed when connecting to the return line. The 3 cost types are summed up in heat generation costs. Also the price developments of the different cost types are considered in the calculations of the