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Influence of different technologies on dynamic pricing in district heating systems: Comparative case studies

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ABSTRACT

District heating markets are often dominated by monopolies in both Denmark and Finland. The same companies, often owned by local municipalities, are usually operating both supplying plants and district heating networks, while the pricing mechanisms are rigid, often agreed upon for one year in advance. The mentioned ownership scheme may cause problems, when one tries to gain a third party access in order to deliver excess heat or heat from cheaper heating plants. In this paper, two case studies were carried out to simulate the district heating systems based on dynamic pricing. Case studies were carried out for Sønderborg, Denmark and Espoo, Finland. The results showed that dynamic pricing fosters feeding the waste heat into the grid, as dynamic pricing reduced the total primary energy consumption and CO_2 emissions in both case studies. In the best scenarios, the weighted average heat price decreased by 25.6% in Sønderborg and 6.6% in Espoo, respectively.

1. Introduction

During the last decade of the 20th century, the European Union (EU) decided to push for liberalization of energy markets of its Member States. The decision mostly referred to power and gas markets. A clear distinction was made between competitive parts, such as electricity generation and supply, and non-competitive parts, such as energy transmission and distribution. One important goal of the transition was to oblige the operators of transmission and distribution systems to grant equal access to the infrastructure to all the interested parties [1].

District heating (DH) sector was left outside of the immediate scope of the energy markets liberalization and different Member States approached it differently. Sweden is the country that went the furthest concerning the DH markets liberalization. Recent research showed that even though DH companies are supposed to be commercial in Sweden, the cost-based approach is still dominating over market pricing mechanism [2]. Furthermore, the authors concluded that still after 10 years from the initiation of the DH markets liberalization, Swedish integrated market for heat has not yet evolved [2]. On the other hand, DH systems in Denmark, both energy generation facilities and infrastructure, are still largely owned by local municipalities. Notable exceptions are the DH systems of Copenhagen and Aarhus which have some sort of dynamic pricing [3].

In Finland, DH systems are natural monopolies inside network, i.e., there is only one DH operator in a network, typically a municipal company, and customers cannot choose their DH supplier. However, customers often have no obligation to connect to the DH network in Finland; they can rather freely choose from different heating technologies. In Finland, DH pricing has typically been rigid and pricing for customers has been based on connection, capacity and energy fees. There has been some development in DH pricing in recent years and some DH companies offer a seasonal-pricing option, in which energy fees are lower in summer and higher in winter, alongside the classical rigid pricing structure. However, neither of these pricing methods represent DH production costs accurately [4]. Opening DH markets has been identified as one of the key aspects to tackle the challenges caused by new European regulations, which are affecting energy production and energy efficiency in Finland [5]. In March 2018, Fortum announced that they are going to progress with opening of DH networks in Finland by announcing publishing of daily waste heat prices on

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their web sites, starting from spring 2018 [6].

A review of different pricing methods for DH has been presented in Ref. [7]. The authors suggested that marginal pricing would have various benefits, including better representation of production costs and reflecting the heat markets as well as motivating the suppliers to reduce the costs of heat production. However, the authors stated that marginal costs could be hard to calculate. Sun et al. proposed two methods for marginal pricing, mainly setting the electricity price and entropy drop, but their methods could not reflect the changes in different heat production technologies [8]. Dynamic pricing possibility for the Espoo DH, Finland, was studied in Ref. [4]. The authors concluded that the open heat market could be beneficial for all parties and that significant economic and energy savings were possible [4]. Different authors carried out a research on the possibility of regional heat market in Sweden [9]. The authors focused on the region dominated by energy intensive industries with a large waste heat potential and results showed that the payback time of integrating DH systems ranged from two to eleven years, depending on the scenario [9].

Industrial and individual consumers could become so called prosumers in the future, if the access to the DH infrastructure were granted to them under the fair pricing mechanisms. In that way, significant amount of waste heat from industry could be fed back to the grid, while excess capacity that consumers sometimes have could be better utilized. Based on a case study in Malmö, Sweden, prosumers with continuous cooling demand could have a notable impact in DH network [10]. The case study also suggested that there has been a prominent amount of low temperature heat available, which could be utilized in DH network [10]. Kimming et al. concluded that the vertical integration of local fuel producers into DH systems resulted in lower costs and emissions in the energy system [11]. Moreover, it was found that both the conditions of the energy market, as well as the type of the heat production system impacts the system emissions from the life-cycle perspective [12]. Furthermore, it was found that the industrial excess heat fed into DH system can be beneficial even when it causes reduced local electricity generation [12]. Another study identified a significant untapped potential of industrial waste heat on the case of Sweden DH systems, confirming that the Third Party Access legislation would be beneficial if adopted [13]. Finally, it was shown that even the introduction of individual prosumers is possible, based on technologies such as solar collectors and heat pumps, although it demands management and control of the issues such as locally lower heat supply temperature, as well as the local changes in velocity and differential pressure [14].

Most of the papers presented here have not studied the potential of dynamic pricing in the DH systems in a systematic manner. No paper that dealt with the marginal pricing in district heating adopted the pure marginal based pricing used in power markets. As it was shown in the literature review that several papers suggested to carry out a simulation of marginal based pricing, this paper filled that research gap. Furthermore, one of the papers detected that it is needed to model the impact of solar thermal collectors, heat pumps and thermal energy storage (TES) on DH markets [5]. In order to fill all of the gaps in the literature presented here, this paper aimed for answering the following research question:

> “What is the potential effect of dynamic pricing based on marginal costs on DH systems?”

The approach used in this paper allowed more realistic evaluation of low marginal cost heat in different periods of the year, being especially relevant for evaluation of future DH systems, when more low marginal cost heat is expected to be used, such as industrial waste heat and solar thermal energy. In order to make the results robust, two case studies were carried out, one for the DH grid in Denmark and one for Finland.

The paper continues with the Methods section, in which the potential mechanism of dynamic pricing in the DH systems is presented, and case studies description. In the Results section, the total turnover of the dynamically priced DH systems, weighted average marginal costs of the heat generation and the CO_2 emissions in different scenarios are shown. The results of the paper are put in the perspective of other DH systems in the Discussion section, together with a discussion on the major uncertainties about the assumptions used in this paper. Finally, the key points are summarized in the Conclusion section.

2. Methods

District heating supply and demand was simulated in similar fashion as the current electricity day-ahead markets operate, such as El-spot market on Nordpool. Heat demand in the DH system was taken as fixed, using the real data obtained for the year 2015. Heat supply was simulated based on the marginal cost of heat generation in each hour. The point where the heat supply and demand curves intersect is the price of heat set for that hour, as it can be seen in Fig. 1.

The marginal heat generation price included variable operating and maintenance costs (O&M), fuel costs, different fees and taxes, as well as the feed-in premium, if eligible. The latter means that only the costs that depend on the amount of energy generated (running costs) are included in the price formation. Capital costs, such as annualized investment costs, are not included in the bidding price formation as those costs are considered as sunk costs, once they have occurred. If one had decided to invest in an energy plant and a certain capacity was installed, the capital costs would need to be paid for no matter on the amount of generated energy. Thus, in the short-term, the operator of the plant will accept any price that is higher than the running costs of the energy plant.

Furthermore, concerning the cogeneration (CHP) plants, electricity income from el-spot market was deducted from the total heat generation costs, while the total fuel costs were included in the marginal price. Using the latter approach, a complicated division between fuels used for power and heat generation was

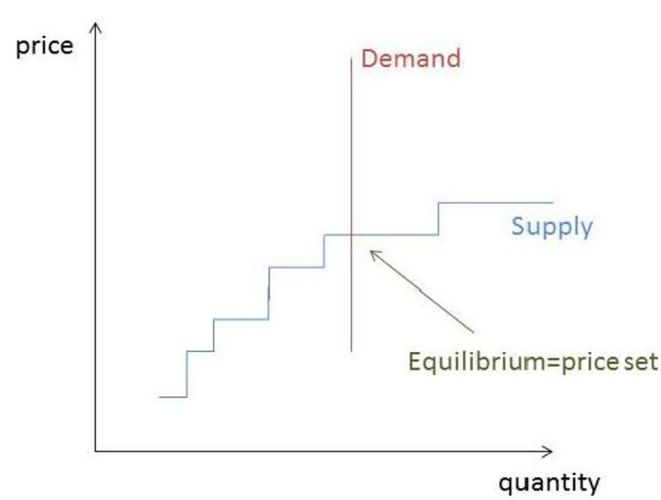

Fig. 1. A representation of the demand-supply curve in the simulated dynamic heat market (vertical demand curve represents the fixed heating demand that was assumed in each hour).