Applied Energy xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

District heating cost fluctuation caused by price model shift

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HIGHLIGHTS

- A survey is carried out to understand the structure of DH price models in Sweden.
- The impacts of two restructured models are analysed.
- The impacts of different shares of different price components are also analysed.
- Provide novel insight of how pricing strategies affect user's consumption pattern.

ARTICLE INFO

Article history:
Received 4 April 2016
Received in revised form 28 August 2016
Accepted 26 September 2016
Available online xxxx

Keywords:
District heating
Price model
Transparency
Peak load reduction
Load pricing strategy

ABSTRACT

District Heating (DH) is considered as an efficient, environmentally friendly and cost-effective method for providing heat to buildings, and is playing an important role in the mitigation of climate change. Nowadays, Swedish DH companies are facing multiple challenges, and in urgent need for new price models to increase transparency and keep the competitiveness. In this paper, a survey is carried out to understand the structure of the present price models. Then, two restructured price models are proposed and compared with the price model most commonly used. To increase the transparency, price models should be based on users' measured consumption profile; while to reduce the peak load, adoption of a pricing strategy based on a load demand component is an effective way. Consequently, users with flat consumption profiles will reduce cost, whereas users with steep consumption profiles will have a cost increase, both when charging the load demand cost based on the maximum daily or hourly peak load.

1. Introduction

A District Heating (DH) system is a centralised system that supplies heat to end-users by distributing steam/hot water through a pipe network. The centralised heat generation benefits from possibilities to utilize energy resources which are difficult to use otherwise (domestic waste, waste heat from industrial processes, etc.) and it is also equipped with more advanced control over air pollution. Therefore, DH is considered as an efficient, environmentally friendly and cost-effective method for heating up buildings, and is playing an important role in the mitigation of climate change. Today, more than 50% of the heat needed for space heating is supplied through district heating systems in Sweden [1].

In spite of the success DH companies have achieved, they are facing tougher and growing competitions from other ways of supplying heat [2]. For example, heat pumps represent an energy efficient technology for heat production. They normally have a coefficient of performance (COP) between 3 and 5, which means that a heat pump can deliver 3 to 5 kWh heat by consuming only 1 kWh electricity. Considering the fact that the DH price is similar to the electricity price [3], DH becomes less and less competitive.

Plenty of researches have been conducted to improve DH system's efficiency or reduce the operation cost, for instance: Lund et al. [4] and Sartor et al. [5] investigated DH companie's potential cost saving achieved by using biomass based combined heat and power (CHP) units; Marbe et al. [6] and Djuric Ilic et al. [7] assessed the efficiency improvement through combining CHP plants with biomass gasification and biofuel production process. However, the cost for DH users was still raised by 31% between 2000 and 2009 in Sweden [8].

Another pressure comes from the general descending trend of heat demand due to the improvement of energy efficiency of buildings and warmer climate [9,10], which will jeopardize DH companies' revenue [11]. The heat demand can be divided into peak load and base load. The base load is normally covered by CHP plant,

Abbreviations: DH, District Heating; EDC, Energy Demand Component; EEM, energy efficiency measure; FDC, Flow Demand Component; FXC, Fixed Component; LDC, Load Demand Component; PS-LD, pricing strategy based on load demand.

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http://dx.doi.org/10.1016/j.apenergy.2016.09.073
0306-2619/

which requires large investment but has very low operation cost; while the peak load is usually covered by boilers burning coal, natural gas or oil, which have small investments but high operation costs. DH companies' profit mainly comes from the base load, consequently, when the base load decreases, DH companies will have less profit. However, on the contrary of the decline of heat demand, the peaks of heat demand becomes even less predictable because of higher frequency of extreme weather [12]. Volatile and extreme peak demand increases the production cost and therefore, worsen the competiveness of DH.

Hence, if DH companies intend to keep competitiveness by reducing price, it is crucial to reduce peak demand at certain level. Pyrko [13] studied the electricity tariff and found that introducing a pricing strategy based on load demand (PS-LD) in the electricity price model could motivate users to change their consumption pattern, (or in other words, shaving the peak demand) to save their energy expense. The same strategy is suggested in [14] for DH. However, it still remains unclear what the effective way is to implement it in the price model and how effective it is on the change of peak load.

The non-transparency of DH price model has also been criticized for a long time [15], and many efforts have been made to enhance the transparency in the area. For example Li et al. reviewed different pricing mechanisms in [16]; the impact of marginal cost strategy on energy efficiency measures (EEMs) has been analysed in local system's level in [17] and [18]; Lundström et al. [19] analysed the impact of seasonal pricing on EEMs; and Zhang et al. [20] and Poredoš and Kitanovski [21] discussed using exergy as an alternative basis for pricing. Whereas, very little has been revealed to guide DH companies or provide DH users proper insight during the process of price model restructuring. Before the restructuring can be introduced, a comprehensible analyse about the present price models is needed to deeply understand the structure of current price models and identify the factors affecting the transparency of DH price model.

Based on the knowledge gaps identified in the literature, the objectives of this paper are (I) to analyse the potential approach about price model restructuring in order to improve the transparency of heat pricing and (II) to investigate the effectiveness of using load demand pricing strategy to motivate users to reduce their peak demand. This work provides a novel insight of how different components of price models and the share of these components would affect DH user's cost during the process of price model restructuring.

The text is organized in the following way: Section 2 presents a comprehensive survey regarding the current price models applied in Sweden; based on the survey results, two restructured price models are proposed to improve the pricing transparency and reduce the peak demand in Section 3; in Section 4, the impacts of the new models on the heat expense of users are estimated to analyse the effectiveness of the restructuring; some discussions about the future work are shown in Section 5 and the major conclusions are summarized in Section 6.

2. Price model survey

In order to understand the structure of current price models, a comprehensive survey is conducted. Price models used by 80 big DH companies are collected from these companies' website. In general, the price models include four components, including Fixed Component (FXC), Load Demand Component (LDC), Energy Demand Component (EDC) and Flow Demand Component (FDC).

In addition to the structure of price components, the share of each component is also important information, which affects users' cost. But it could not be calculated without knowing the heat consumption profile of users. In order to analyse it, several assumptions are made to form a typical multi-family house as an example. The monthly DH consumption of the typical house used in the survey is shown in Fig. 1.

- Annual DH consumption is 193 MW h, same as the annual cost report of facilities conducted by Swedish housing association.
- 25% of heat is used for domestic hot water and distributed evenly throughout the year.
- 75% of heat is used for space heating, distributed in proportion to degree-days over a normal year (calculated from Västerås's temperature statistic between 1960 and 2014, source: Swedish Meteorological and Hydrological Institute).

The share of each component in those collected price models is shown in Fig. 2, in a descending order regarding the share of EDC.

FXC represents the cost that a user needs to pay for staying in the network. FXC is generally related to the user's estimated/measured peak load demand, which is further staged into certain levels. Fig. 3 shows the fixed fee in Göteborg Energi's price model, no cost charged for peak demand under 50 kW, 8500 kr for peak demand between 50 and 100 kW, and so forth. 60% of investigated price models have this component, but it accounts only for very small fraction (1% in average) in the typical house's total DH cost.

LDC is usually used to cover DH companies' cost to maintain a certain level of capacity for peak load, investment costs of new facilities, depreciation, etc. Most of included price models determine LDC basing on the equivalent annual consumption, which is corrected according to a typical normal year. LDC can also be determined according to the pricing strategy based on load demand. User's LDC cost depends on the capacity reserved for the specific user. For example, DH companies usually set a price for a unit of load demand (usually in SEK/kW), and use measured or estimated peak load demand to calculate the cost. The survey shows that 51% of investigated price models use assigned consumption hour method for LDC. Other methods include: using the consumption of previous year's/winter's (14%), using real measured peak demand (12%), using load signature (6%) and using subscribed demand (4%). The later three methods are directly related with user's real consumption profile and could, to some extent, enhance the transparency in price model. In the typical house's total DH cost, LDC accounts for about 28% averagely. There are 13% of price models without LDC.

EDC is used to cover the production cost of DH companies, which is mainly the cost of fuel. It exists in all price models, which is charged based on user's energy consumption. 63% of included price models use constant price for EDC. But constant price is not able to reflect the real production cost as DH system has much lower operation cost at base load and higher operation cost at peak load. 33% of price models use seasonal price, which is high during the peak season (usually winter) and low during other time. Other

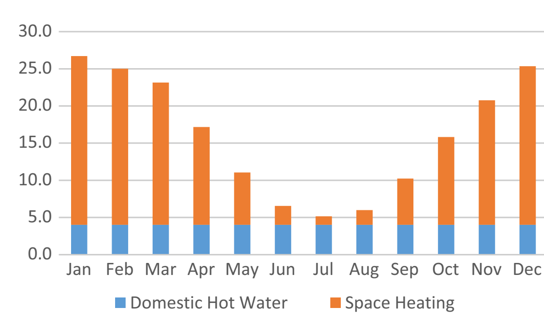

Fig. 1. Monthly DH consumption of the typical house.

Please cite this article in press as: Song J et al. District heating cost fluctuation caused by price model shift. Appl Energy (2016), http://dx.doi.org/10.1016/j.apenergy.2016.09.073