



An assessment of district heating research in China



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ABSTRACT

The recent growth of the Chinese district heating sector has been very high. No other country in the world can show the same growth rate during the last decades. The heated building area increased six times between 1995 and 2008. China has also enjoyed strong growth of scientific articles and papers about district heating in recent years. One third of all international scientific journal articles and conference papers about district heating came from Chinese scientists during 2010–2012, while Swedish scientists accounted for one quarter according to the Scopus scientific search engine. It is important to identify the Chinese district heating research to judge the potential for future collaborative research on district heating systems between Sweden/Europe and China. The 205 international publications on district heating by Chinese scientists published until 2013 have been mapped and summarised with respect to demand, supply, technology, market and environment. More diversified heat supply with renewable source was grasping the Chinese interest, since many new systems have been established, having more degrees of freedom when choosing various heat supply and technology options. The Chinese district heating systems were compared with sustainable district heating solutions in Sweden. Both countries would benefit from future research cooperation.

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1. Introduction

China is the second largest building energy user in the world, ranked first in residential energy consumption and third in service sector energy consumption [1]. China has also the highest carbon dioxide emissions in the world, representing about 27% of all global carbon dioxide emissions [2]. The average annual growth rate of carbon dioxide emission from Chinese urban district heating has been 10% and this sector was responsible for 4.4% of all carbon dioxide emissions in 2009 [3]. Coal is the primary fuel in Chinese heat supply. About 40% of the air pollution in China comes from coal dust [4]. In order to improve energy efficiency and reduce carbon dioxide emissions, many Chinese scientists work within the field of district heating and cooling.

In the 1950s, both China and Sweden started to build district heating systems. Denmark became the guiding example for Sweden, while the former Soviet Union became the guiding example for China. Both these guiding examples started their first district heating systems in the 1920s. One important feature of Danish district heating was customer heat demand and flow control in

each substation. This feature gave automatically a proper flow allocation. The Russian systems lacked this feature, and worked with balancing valves creating average constant flow in the system. This Russian principle is a major drawback in system functioning, giving severe flow allocation problems in heat distribution networks.

The growth of the Chinese district heating sector has been very rapid during recent years. No other country in the world can show the same rapid growth of the district heating during the last 10–15 years. Heated building area and total pipe length increased 8 and 17 times, respectively, between 1995 and 2012 according to the Chinese district heating statistics [5]. The Scandinavian district heating technology is characterized by high quality and has been a prerequisite for high market shares for district heating reaching about half of all building heat demands in Sweden, Denmark and Finland.

To our knowledge, no established research cooperation exists between China and Sweden/Europe today concerning district heating and cooling. However, Tsinghua University participates in the Danish 4DH project between 2012 and 2017 [6]. Denmark and China have established technology cooperation according to [7]. An overview of the technological differences in district heating systems between China and Denmark was published in Ref. [4].

Sweden has had district heating research since 1975 in various national research programs, but most of the final research reports

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were written in Swedish, making them unknown for foreign researchers. Also many Chinese research projects are unknown in Europe. There should be a future value for the Swedish district heating sector to undertake a benchmarking against the rapidly growing district heating sector in China. Many newly built Chinese district heating systems have had more degrees of freedom to consider in their initial start and the following expansion, while old systems have been locked in their basic technology choices. The existing Swedish district heating systems have a very strong market position with more than half of all Swedish building spaces connected after 60 years of expansion, giving less degree of freedom for the future. An important issue for a future benchmarking is how the possible technical choices influence the district heating research in China and Sweden.

The Scope scientific search engine was used for the analysis of the current district heating research in China, the articles from search engine were mainly written in English. Articles written by Chinese district heating scientists in international scientific journals have been mapped according to markets, demands, loads, supply, environmental impact, distribution technology, substations, system functioning, as well as economics and planning. These articles have been assessed and summarised. A comparison between Chinese district heating and Swedish district heating has also been performed. The analysed articles and papers were limited to the result of the Scope scientific search engine with the search word 'district heating'.

The main purpose of this paper was to identify the Chinese district heating research to judge the potential for future collaborative research on district heating systems between China and Sweden/Europe. The major research questions identified were:

- How can the scientific articles on district heating in international energy journals written by Chinese scientists be characterised?
- What are the similarities between Chinese and Swedish district heating systems?
- What are the differences between Chinese and Swedish district heating systems?
- What can Sweden/Europe learn from Chinese district heating experiences?
- What can China learn from Swedish/European district heating experiences?

2. Analysis of research publications on district heating

2.1. International analysis

Between 1970 and 2013, 5627 international scientific publications were written by using the 'district heating' label, according to the scientific search engine Scopus, as shown in Fig. 1.

Numbers of district heating publications from Germany are in first place since the journal Euroheat & Power (formerly Fernwärme International) has published district heating articles for more than forty years in Germany. The district heating articles from Sweden are still in second place over countries since 1975, USA comes in third place, and China is on fourth place. However, one third of all international district heating journal articles came from Chinese scientists during 2010–2012. This means that the Chinese academic researchers are supporting the expansion the Chinese district heating systems by their increased number of publications.

Fig. 1 reveals also an interesting curiosity, the annual number of international district heating publications seems to be proportional to the real international crude oil price. This conclusion shows that the world is looking the energy efficiency aspect of district heating

when energy prices are high.

2.2. Analysis of Chinese district heating papers

Chinese authors have written 232 of the 5627 publications about district heating according to the Scopus scientific search engine. However, 16 were non-district heating papers and 11 were only about district cooling, since the Scope scientific research engine seems to regard the labels 'heat generation', 'heat source', and 'heat load' as 'district heating', so the total number of publications became 205. 28% of the district heating papers have been published in conference proceedings and 27% in the Elsevier international journals, of which 19% were published in the major Elsevier energy journals, such as Energy, Energy Policy, Applied Energy, and etc. Many universities in China have also their own journals, thus 20% of the Chinese district heating papers have been published in university owned journals.

The first international Chinese district heating paper [9] was published in the special workshop issue of The International Journal of Energy in 1984. Eight years later, the second international Chinese district heating journal paper [10] was published. These two papers focused on heat supply from nuclear energy for district heating.

The chapters in the new international district heating and cooling textbook [11] have been used as subject classification to analyse these papers. The identified papers are dominated by 81 papers about heat and cold supply methods, since many old inefficient and high pollution coal-fired boilers need to be replaced, and 49 papers focus on system functioning, as shown in Table 1.

Publications on energy, heat, and cold market were very few, since the Chinese district heating systems by tradition have been part of the welfare system without competition in heat market for buildings. Another low focus research field was on heat and cold distribution technology, since all five papers have been published since 2009. The earlier technology was based on former Soviet Union standards, and this need to be improved with new enhanced technology. Recently, three papers on heating metre reform have been published, since Chinese district heating systems are expected to turn from public welfare systems into commercialised systems.

2.3. Focused research areas by Chinese researcher

The topic of heat and cold supply methods are the most interesting subject for Chinese researchers during the analysed years. The system functioning topic was the second most interesting area after 1996. Recently, substation technologies grasp the Chinese researchers' interest as well.

2.3.1. Heat supply

Table 2 summarised papers about heat supply methods during 1984–2013. Early papers on heat and cold supply are mostly related to nuclear energy, later research focus more on renewable energy sources, such as geothermal and solar heat. Waste heat from thermal power plants (combined heat and power) and industrial processes are recently focused on. Boilers generate about half of all heat supply in district heating systems [12], but there was only one paper [13] published in 2011 on analysing 472 heating boilers in Tianjin. The statistics from these boilers showed very low energy efficiency. Absorption heat pumps and Combined Heat and Power (CHP) are the main direction of the development, as well as Combined Cooling, Heating, and Power (CCHP). The recently published papers on heat supply method align with most of the five current, suitable, strategic local heat and fuel resources for district heating. These five strategies are CHP (usable upgraded excess heat from thermal power station) plants, waste-to-energy plants (usable heat

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