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Barriers to and enablers of district cooling expansion in Sweden

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ABSTRACT

Although Sweden is a northern country with fairly low outdoor temperatures most of the year, its district cooling (DC) systems are expected to expand. Some actors claim that there is potential for at least a doubling of DC in Sweden. One reason for this is that demand for cooling increases with the increased use of electronics such as computers, resulting in higher indoor temperatures from waste heat production. Although DC should have considerable growth potential based on its convenience and climate benefits, its growth has been surprisingly slow.

This article discusses the barriers to and enablers of DC expansion. We examine how energy companies, property owners, and tenants perceive the barriers to and enablers of installing and using DC. How do these actors view the present and future need for cooling? What would make DC more attractive according to these actors? These questions were studied using surveys and in-depth interviews.

The results indicate that lack of information is the most important current barrier to DC expansion, a barrier that could easily be addressed, making information an enabler of DC. Earlier grid-based energy systems in Sweden were established through public–private collaboration, and such collaboration could promote the ongoing expansion of DC. For example, municipalities played an important role when district heating was built, but this has not been the case for DC. Another possible enabler is the eco-labelling of DC, which has so far played a minor role in the Swedish system.

1. Introduction

The increasing temperatures accompanying climate change and the greater use of electrical equipment that produces waste heat will together increase the need to cool indoor environments such as shops, offices, industrial facilities, and hospitals in order to maintain comfortable indoor temperatures (Fahlén et al., 2012; Rodriguez-Aumente et al., 2013; SOU (Swedish Governments Official Reports), 2007; Werner, 2016). This applies not only to countries in warmer areas, but also to those in the northern hemisphere. Although Sweden is situated in a geographic zone where, most of the year, the outdoor temperature is relatively low, cooling has become an issue (SOU (Swedish Governments Official Reports), 2007; Werner, 2004). There are various technologies for cooling premises, among which district cooling (DC) has been identified as effective for reaching overall strategic energy goals (EU Directive, 2009/28/EC; Gang et al., 2016a). This paper considers the enablers of and barriers to the expansion of DC, based on the Swedish experience.

The first known DC systems were built to serve the Rockefeller Centre in New York and the U.S. capital buildings in Washington, D.C. in the 1930s. The expansion of DC in Sweden took off in the early 1990s (Abrahamsson and Nilsson, 2013) and today there are about 30 DC-producing energy companies in the country. DC delivery in Sweden increased by 63% between 2004 and 2015, with around 1 TWh of DC being delivered in 2015 (vs. around 55 TWh of district heating delivered per year) (Svensk fjärrvärme, 2015, 2016). DC can be produced in various ways, for example, using compression chillers, absorption chillers, or deep lake water cooling. Earlier studies on DC focus mainly on technical aspects of the system and for example the latest major comprehensive review article (Gang et al., 2016b) about DC do not include a customer perspective. Here we do not analyse DC technologies, but rather consider the various aspects and preconditions for expanding the use of DC as such. Few residential or other buildings in Sweden use this type of

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cooling system, and as the cooling of premises seems to be the main DC market in Sweden (Abrahamsson and Nilsson, 2013), this study will focus on premises.

DC systems in Sweden, as in Europe, have considerable expansion potential, and a doubling of the Swedish DC capacity in the near future is often said to be realistic (Svensk fjärrvärme, 2016; Werner, 2016). Various development paths support an increase in the demand for cooling. DC is generally regarded as sustainable, especially when it replaces electricity-based cooling (see e.g. Ameri and Besharati, 2016; Fahlén et al., 2012; Gang et al., 2015; Lake et al., 2017; Werner, 2004, 2016). Although DC should have expansion potential based on its convenience and climate benefits, its growth in Sweden has been surprisingly slow.

The overall aim of this paper is to discuss the barriers to and enablers of DC expansion. The results are based on the Swedish experience, though we will address these issues in a wider context as well. In this paper, we will examine how energy companies, property owners, and the tenants of premises perceive the barriers to and enablers of the installation and use of DC. How do these actors view the present and future need for cooling? What would make DC more attractive according to these actors?

2. Theory: large technical system and barriers

In Sweden, state and municipal governments have traditionally been key actors in building and operating major public works systems, such as water and sewage, electrical, and district heating (DH) systems. One frequent argument for this has been that the profits from such enterprises should not accrue to private interests, but rather benefit the Swedish citizenry, for example, in the form of lower tariffs. This is also one reason why most DH companies were run as municipal services up until the 1980s (Palm, 2006). Over the last 25 years, most of these services have been converted into municipal corporations. Most Swedish DH corporations are still under municipal ownership, although there has been a trend towards increased privatization in the DH industry (Magnusson, 2012; Magnusson and Palm, 2011).

DC is similar in many ways to DH, as it involves the centralized production and distribution of energy, but in the form of cooling. In DC, chilled water is delivered via underground pipelines to cool the indoor air of buildings within a district. Each building connected to the system has a heat exchanger, which uses the chilled water to lower the temperature of air passing through an air conditioning system (Werner, 2004). In Sweden, a big difference between the systems is that DH is well established, widely distributed, and regulated by law, while DC is a more recently introduced concept still in an expansion phase. Furthermore, over the years, several governmental investment programmes have contributed significantly to the pace and extent of DH expansion in Sweden (Byman, 2004). Municipalities in collaboration with local energy companies have played a key role in this (Palm, 2004; Summerton, 1992). So far, there have been no similar initiatives to promote DC expansion. This makes DC interesting to study from the perspective of the enablers of and barriers to introducing new large technical systems in a country.

The development of infrastructural systems such as DC has often been analysed through the lens of the large technical system (LTS) framework. This framework, developed by Thomas B. Hughes (1983), has mainly been used to analyse the establishment of systems in phases, i.e. the invention phase, expansion phase, technological transfer phase, and, finally, the momentum phase, when a system acquires autonomy from its environment and becomes difficult to change. This study focuses on the expansion phase.

Large technical systems can be viewed as natural monopolies. What characterizes a natural monopoly is that one firm can supply a market's entire demand for a good or service at a lower price than two or more firms. In a DC system it is for example more cost effective for an existing DC company to expand its operations than it is for a new company to establish itself in the same area. The entrance of yet another company into the local market does not have the healthy regulatory effect associated with an optimal competitive situation (Palm, 2007). The DC industry's character as a natural monopoly implies that there is room for only one company within a geographically delimited area. In DC, it is the *distribution* of chilled water that is considered to constitute a natural monopoly; the *production* of chilled water could, in theory, be open to competition. The ideas about where competition can and cannot work in DC (and DH) is ongoing discussions among policymakers and practitioners and how the arguments develops dependence where, who and when a discussion takes place. Customers who choose DC today are referred contractually, technically, and financially to a single seller, so that DC also exerts a certain “lock-in” effect. Changing cooling sources is an option, but the costs associated with such a switch make it financially infeasible or, in any event, difficult to accomplish, which is why there is a lock-in effect.

DC can at the same time sometimes be viewed as a near monopsony, as the market may effectively comprise only one customer for whose business the sellers must compete (Jonsson, 1999). One example in relation to DC is that, for example, a hospital can have such a dominant role that the seller's financial situation is dependent on retaining it as a purchaser of DC. The DC company's bargaining chip in this context is, of course, its power to shut off the supply of DC (Palm, 2007).

From earlier research into grid-based systems (e.g. gas, DH, electricity, railways, and broadband) we know that there are five key issues to be solved when establishing a new large technical system:

- technical uncertainties concerning, for example, the risks of the technology in terms of, for example, reliability and interference with the environment and plant life;
- inertia in the system, meaning that it takes time from system initiation until the system is ready for use; The distribution grid has a lifespan of up to 100 years. If doubt occurs about the system's expansion potential, that will be one of the major threats to the system.
- economic conditions characterized by large initial investments in production and distribution facilities and the significant uncertainty of future profitability;
- the organizational form of the business and, in particular, the question of whether cities should be responsible for construction and operation or should transfer the systems to private contractors; and
- the legal relationship between supplier and customer. There is substantial uncertainty about subscriber behaviour and there are strong interdependencies between subscribers and their suppliers. Summerton (1992) has demonstrated the importance of having a major customer on board when initiating a grid system. Historically, municipally owned housing companies in Sweden have played a major role in ensuring an initial market for district heating.

These five issues apply to more or less all grid-based supply systems. From barrier theory, it is possible to identify and specify further hindrances to the establishment of DC.

2.1. Barriers and enablers relevant to DC

When barriers are discussed in relation to energy efficiency, and