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Low-carbon district heating in Sweden – Examining a successful energy transition

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ABSTRACT

District heating (DH) systems may contribute to reducing the use of fossil fuels for heating purposes since they enable the use of waste heat and facilitate the use of renewable energy sources. This paper focuses on the transformation of the Swedish DH systems with regard to energy supply in 1960–2011. Swedish DH production was completely dependent on oil until the late 1970s, while today it is dominated by biomass and other renewable energy sources. The objectives of this paper are to describe and explain the fuel transition in the context of the main events that have characterized the development of the Swedish DH sector. For this purpose, we employ theories and approaches grounded in the literature on systems of innovations, especially the Multi-Level Perspective. The study shows that the transition involved a series of steps. Initiated by the oil crises in the 1970s the oil-based regime collapsed rapidly, while the growth of the biomass-based regime was a steered process governed by actors and supported only by external events. The lessons learned from the transition towards low-carbon and more sustainable DH systems in Sweden could be useful in the challenging task of steering future energy transitions in other countries and sectors.

1. Introduction

Fossil fuels such as oil and natural gas are the dominating energy sources for heating purposes in much of the world [1]. This reliance on fossil fuels is not sustainable from the climate perspective, or with regard to security of supply. District heating (DH) systems may contribute to reducing the use of fossil fuels for heating purposes since they enable the use of waste heat, and may facilitate the use of renewable energy sources. DH involves the distribution of heat from one or several heat production plants to a number of consumers in a city or town through a network of pipes. Due to the scale involved in DH, these systems provide the opportunity to use unrefined biomass, deep geothermal heat, industrial waste heat and heat recovered from waste incineration. These systems also enable combined heat and power (CHP) production. DH systems may thus reduce the use of fossil fuels for heating purposes and contribute to energy efficiency of the energy systems. In future energy systems with large proportions of intermittent power, such as wind and solar power, the DH systems could also have the important task of balancing the power grid by accommodating excess power production [2].

DH systems are very common in European countries such as Finland, Germany, Denmark, the Baltic countries and Eastern Europe [3], as well as in Russia and China [4]. This paper focuses on Sweden, where DH systems can be found in essentially all municipalities, accounting for 57% of the energy supply for space heating and hot tap water in the residential and service sectors [5]. Apart from the high penetration rate, the Swedish DH sector is an interesting case due to the profound transformation it has gone through with regard to the sources of energy employed. Until the late 1970s, the sector was completely dependent on oil, while today biomass is the dominant energy source, accounting for 45% of the energy supply [5]. This paper focuses on the transformation of the Swedish DH sector with regard to energy supply, a development that can be described as a low-carbon, sustainable energy transition, due to the societal benefits of breaking the dependence on fossil fuels in the heating sector.

The historic development of the Swedish DH sector has been addressed in previous research. The literature in this area mainly focuses on the introduction and expansion of DH networks, although changes in energy supply are also touched upon (see, for example [6,7]). These studies show that development has been shaped by a number of institutional factors, including strong

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municipalities and various national policies and regulations, but also other circumstances, such as the lack of alternatives such as natural gas, which was not available in Sweden until 1985. Magnusson [8] takes more recent developments as his starting point to argue that the Swedish DH sector is heading towards a stagnation phase due to decreasing heat loads and saturated markets. There are also a number of studies focusing on the local (political) processes behind the decision to build or expand DH systems in a particular municipality (e.g. [9–11]).

In this paper we examine the development of the Swedish DH system at national level in the period from 1960 to 2011, with particular emphasis on the source of energy. The aim of this paper is twofold. The first is to describe the transition from oil to biomass and other renewable energy sources in the context of the main events that have characterized the development of the Swedish DH sector. The second is to explain this transition of energy supply. For this purpose we employ theories and approaches grounded in the literature on systems of innovations [12] and, in particular, the Multi-Level Perspective (MLP), upon which much of the systems innovations literature is based [13,14]. The MLP is a flexible framework that can be applied to analyze transitions interpreted as encompassing economic, technological, institutional and socio-cultural domains [15]. Our study is based primarily on empirical material drawing upon scientific literature, government official reports and bills, reports from relevant Swedish government agencies, official statistics and five interviews with actors currently or previously involved in the Swedish DH systems. The interviews focused mainly on the early period of this study (1960–1980), for which less documentation was available. The interviewees included two CEOs (one retired) of two fuel procurement companies, one retired employee at Sydkraft (now E.ON), one professor emeritus at Lund University and a communicator at the Swedish Bioenergy Association (SVEBIO).

The case of DH in Sweden is a rare example of a successful transition from fossil fuels to renewable energy sources. In many countries this type of transition is viewed as a societal goal in sectors as diverse as transport, electricity generation, heating and cooling, and agriculture. However, experiences associated with this type of transition are often characterized by barriers, problems and failure. This study originates from the assumption that previous transitions may provide knowledge on the processes and dynamics involved in system transitions [16] that may be relevant in initiating or steering future transitions [17]. Understanding how a transition pathway may unfold is vital in the challenging task of steering future transitions, and studies of successful cases of innovation and transition can contribute to the field of energy studies [18].

In Section 2 we illustrate the analytical framework employed in this study and the theoretical basis upon which it was developed, i.e. the MLP of transitions. Section 3 describes major developments in the DH system in Sweden between 1960 and 2011, identifying three key periods: (i) expansion of DH systems fuelled by oil (1960–1972); (ii) the oil crises and fuel diversification (1973–1989); and (iii) the increasing dominance of biomass (1990–2011). In Section 4, we analyze the process and dynamics of the transition focusing on two periods of substantial/extensive change: regime collapse and regime formation. The results of the analysis are discussed in Section 5, where the main conclusions of the study are also presented.

2. Systems of innovations and transition pathways

Academics have shown increasing interest in the dynamics of system transitions and innovations. An important approach in this respect is the MLP in which transitions are regarded as systems of innovations, i.e. as changes from one socio-technical system to another [19]. The concept of socio-technical systems emphasizes the interdependence and co-evolution of material and social structures (e.g. policies, technologies, markets) which over time evolve into a stable configuration that fulfils a societal function such as providing indoor heating, electricity or water [20]. The structural components of socio-technical systems are: (i) material and technical artefacts, (ii) networks of actors and social groups, and (iii) institutions, or the formal, normative and cognitive rules that guide the activities of the actors [13]. A key feature of the MLP is that transitions result from the interplay between dynamics at three levels: micro-, meso-, and macro-. At the meso-level, socio-technical *regimes* represent the dominant ways of fulfilling a societal function [21], including “engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures” [13]. Socio-technical regimes are stable and their development is path-dependent due to mechanisms such as vested interests, organizational capital, sunk investments (in infrastructure, production lines, skills), stable beliefs, etc. [19]. At the micro-level, *niches* form the socio-technical environment where novelties emerge [22,23]. Finally, at the macro-level the *landscape* includes all exogenous elements that affect the development of niches and regimes, but which are largely outside the influence of niche and regime actors [13,24]. Landscape elements may not change, or change only slowly over time (e.g. change in climate), or may change very rapidly (e.g. oil price hikes) [25].

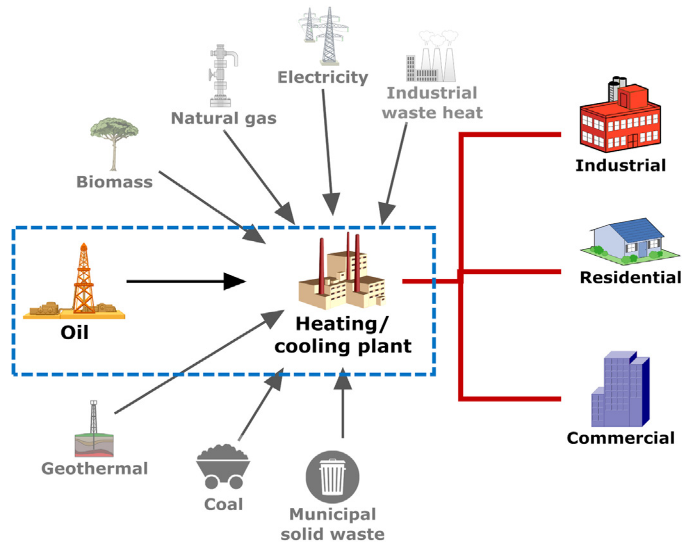

Fig. 1. Technical components of the oil-based DH regime.

To analyze the transition from oil to renewable energy sources in the Swedish DH system, we employ an analytical approach based on the MLP. We consider oil-based DH as the socio-technical regime at the beginning of our analysis since oil combustion was the main (only) way of producing DH in Sweden throughout the 1960s and early 1970s (Fig. 1). To delineate the boundaries of the regime, we distinguish three dimensions: (i) the technological system composed of material and technical artefacts which enable the supply of energy feedstock and its transformation into district heat; (ii) the social system formed by networks of actors and social groups that carry out, or influence the process of feedstock supply and transformation into heat; and (iii) the institutional framework, which includes the formal, normative and cognitive rules that guide the