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Research paper

The introduction and expansion of biomass use in Swedish district heating systems

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ABSTRACT

District heating satisfies about 60% of the heat demand in Swedish buildings. Today, more than two thirds of the heat supply to the district heating systems is based on biomass and waste, and biomass alone accounts for about half of the heat supply. The purpose of this paper is to present the Swedish experiences of introducing and expanding the use of biomass in the district heating systems and to identify the main drivers behind this development. Our five research questions and the corresponding conclusions consider the driving forces from energy policy tools and local initiatives, the biomass prices, the established infrastructures in forestry and district heating, the technology paths for biomass conversion, and finally the future challenge of competing uses of biomass.

1. Introduction

Biomass has become an increasingly important energy source in Sweden over the past three decades. In 2013, biomass and waste accounted for almost a quarter of the Swedish energy supply, which is exceptional among high-income countries [1]. Biomass is used in a number of sectors, but the development of biomass has been particularly impressive in the district heating sector. Today almost half of the Swedish district heat is generated from biomass [2].

District heating systems were introduced in the major Swedish towns in the 1950s and the systems rapidly expanded and spread to other towns during the 1960s, 70s and 80s [3,4]. Today, district heating systems are found in almost all Swedish municipalities and account for about 60% of the heating of buildings in Sweden [5]. The energy supply in the district heating sector has changed dramatically during the past three decades. Until 1980 the energy supply consisted almost entirely of oil, while oil and other fossil fuels accounted for only 7% of the energy supply in 2014 [2].

The purpose of this paper is to reveal the aggregated Swedish experiences of introducing and expanding the use of biomass in the district heating systems. More specifically, this paper aims to answer the following research questions:

i. Which policies and policy instruments have promoted and shaped the use of biomass in district heating systems?
ii. How have the biomass prices and the economics of biomass developed during the biomass expansion?
iii. How has the supply of biomass been achieved?
iv. What technical paths have enabled the transition to biomass in the district heating sector?
v. What are the prospects of using biomass in future district heating systems?

There are a number of studies that address the expansion of bioenergy more generally in Sweden (see e.g. Refs. [6–11]) and studies that address the development of the Swedish district heating systems and their energy supply more generally [3,4,12]. The authors are, however, not aware of any paper that specifically address the biomass expansion in the Swedish district heating systems. The novelty of this paper is that it provides a comprehensive analysis of the use of biomass in the Swedish district heating systems over the past 35 years and analyse this topic in more detail. This paper also includes a discussion on the prospects of using biomass in the district heating systems in the future.

The method used for this paper is to some extent a review and

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synthesis of the existing literature, some of which were cited in the previous paragraphs. This paper, however, also updates this literature by including more recent developments, and it presents new graphs that have been produced by the authors based on our processing of long time series of public statistics. Apart from the literature and statistics, this paper draws on the tacit knowledge of the authors who in their research have followed the development of the Swedish district heating and bioenergy sectors for many years.

Our aim with this paper is primarily to share the Swedish experiences of introducing and expanding the use of biomass in the district heating systems with an international audience since this development is fairly well-known in Sweden, but not documented as performed in this paper. In towns and cities around the world, district heating systems are now increasingly seen as an infrastructure that could facilitate the transition to low-carbon energy systems. One example of this is UNEP's recent launch of The Global District Energy in Cities Initiative [13]. The experiences from Sweden, being an early adopter of biomass in the district heating systems, may serve as inspiration to policy makers and various actors in other countries that have the ambition to develop low-carbon district heating and energy systems.

2. Bioenergy in Sweden

Biomass is a very important energy source in Sweden. In 2013, the Swedish use of biomass and waste amounted to 483 PJ, thus accounting for 23% of the national energy supply or 8% of all biomass and waste used in the European Union [1]. The Swedish use of biomass is exceptional among high-income countries. Only Finland uses more biomass for energy purposes on a per capita basis (Fig. 1).

Fig. 2 illustrates the Swedish use of biomass in different sectors in 2013. Almost half of the total biomass consumption (231 PJ) was used in the energy sector for generation of electricity and district heat. In fact, one quarter of all district heat generated from biomass and waste in the EU was delivered in Sweden [1,14]. Industry also uses large amounts of biomass for energy purposes. In 2013, industry used 175 PJ of biomass to generate process heat. Biomass is also used in electricity production in industry, but this is attributed to the energy sector in the IEA statistics. The forest industry, i.e. pulp and paper mills and sawmills, accounts for most of the use of biomass in industry. The use of biomass in individual heating systems in residential, commercial and public buildings amounted to 47 PJ in 2013 ("other" in Fig. 2). This biomass use mainly consists of firewood and wood pellets that are used in single houses and farms. Finally, about 30 PJ of biomass-based fuels were used in the transportation sector. These fuels consisted of biodiesel, ethanol and biogas.

Apart from the biomass-based transportation fuels, essentially all biomass used in Sweden originates from the forest. Sweden has large forests resources; productive forest land makes up about 57% of the total land area [15]. Biomass from agricultural land, such as energy crops and agricultural residues, plays a minor role in the Swedish use of biomass. Despite various efforts to promote the cultivation of willow, a perennial energy crop that is grown as short rotation coppice, willow wood chips makes a small contribution (1–2 PJ in 2013) to energy supply [16]. Apart from that, wheat and barley are grown for the production of ethanol and rapeseed for the production of biodiesel. Biogas is mainly produced from sewage sludge and food waste from food industries, households and restaurants.

3. The district heating context

3.1. The fundamental idea of district heating

The fundamental idea of district heating is to recover heat from other processes that use primary energy or to use renewable primary energy resources [17]. The three major strategic heat recovery resources are combined heat and power (CHP), waste incineration, and industrial processes. Solar, geothermal, and biomass energies are examples of renewable energy sources that are used in district heating systems. The recovered or generated heat is distributed in pipe networks to substations that transfer the heat to customers to cover their heat demands. Due to the investments required in distribution infrastructure and due to distribution losses, district heating is mainly competitive in dense urban areas and less

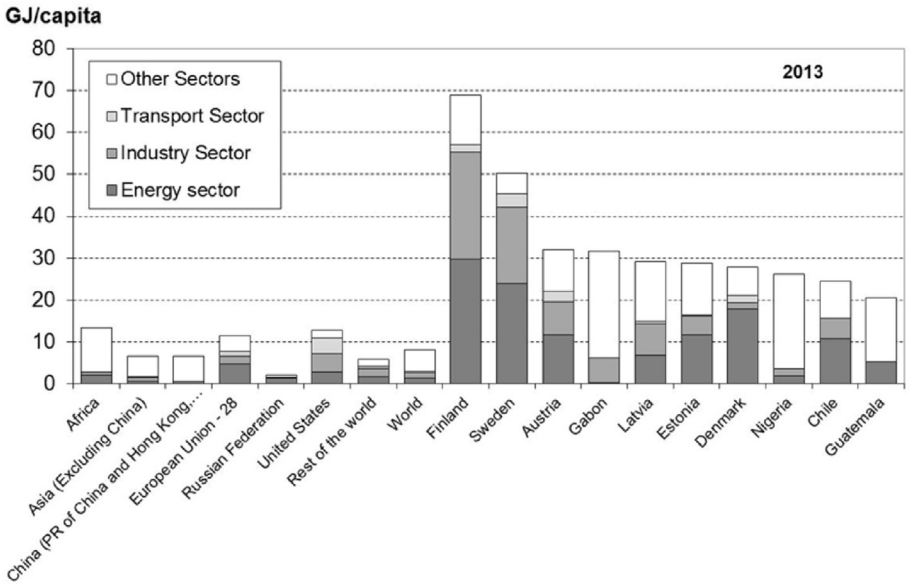

Fig. 1. Primary energy supply of biomass and waste per capita in some global regions during 2013 and in the ten countries with the highest per capita supply of biomass and waste, derived from Refs. [1] and [14].