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The emergence and troubled growth of a 'biopower' innovation system in Sweden

Staffan Jacobsson*

Environmental Systems Analysis, IMIT and RIDE, Chalmers University of Technology, 412 96 Gothenburg, Sweden

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Abstract

Biopower, i.e. production of power using biomass, has a tremendous potential to deliver CO_2 neutral energy in the Nordic countries. This paper analyses the evolution of a biopower innovation system in Sweden where particular attention is given to current driving forces and obstacles to a large-scale diffusion of biopower. In the 1980s and 1990s, this innovation system went through a successful 'formative phase' in which all the constituent components of the 'infant' system emerged. With the introduction of green certificates and emission trading rights, incentives were created that were large enough to shift the system into a 'growth phase', where the extensive district heating system and voluminous production in the paper and pulp industry can be used to produce power on a large scale in CHP plants. An investment boom is now underway and output of biopower is rapidly growing. Yet, there are still substantial obstacles to a realisation of the full potential of biopower. Three of these are outlined and an associated set of policy challenges are specified.

Keywords: Biopower; Sweden; Policy

1. Introduction

The dominance of fossil fuel in the world energy system is associated with clear environmental and climate challenges. A wider use of renewable energy technology is seen as one way of meeting these challenges. For instance, the European Union aims at increasing the share of renewable energy of the supply of electricity from about 14 per cent in 1997 to 21 per cent by 2010 (Commission of the European Communities, 2005) and a higher share is about to be set.[1] To obtain, and go yet further beyond this share, a range of renewable energy technologies need to be diffused. Whereas wind and solar power are diffusing rapidly in some countries, the European Union has recently pointed to a poor realisation of the potential of biomass electricity (Commission of the European Communities, 2005).

Since the early 1970s, biomass has greatly expanded its share in the Swedish energy system in a process that has been labelled a 'quiet revolution' (Kåberger, 2002). This growth has not ceased and biomass accounted for 110 TWh[2] of the Swedish energy supply in 2004—up from 48 TWh in 1980 (Energimyndigheten, 2005a, Table 9). Yet, until very recently, nearly all of the energy was used in the form of heat only. A large potential for expanding power production in biomass-fuelled combined heat and power plants (CHP) was, thus, built up. This was noted by the Commission (2005, p. 35), which pointed to Sweden as lagging behind Finland and Denmark in realising its potential. Two smaller market formation programs for biopower (CHP) were implemented in the 1990s, but it was only with the introduction of tradable green certificates in May 2003 and, in 2005, emission trading rights, that appropriate incentives were begun to be put in place in order to enable biopower to begin to realise its inherent potential.

*Tel.: +46 31 772 1213; fax: +46 31 772 2172.
E-mail address: staffan.jacobsson@chalmers.se

[1] Commission of the European Communities (2007, p. 14) suggests that renewables have the potential to provide around a third of EU electricity by 2020.

[2] Total energy supplied was 647 TWh, but out of these, conversion losses in the nuclear power stations amounted to 149 TWh (Energimyndigheten, 2005a).

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The purpose of this paper is to analyse the diffusion of biopower in Sweden and, especially, to specify the current key policy challenges for realising the longer-term potential of biopower in Sweden. This potential is not automatically realised with the new incentives as (i) the uncertainty facing investors is high, (ii) the costs associated with green certificates have turned out to be very high, which means that there may well be a back-lash as and when the order of magnitude of the costs are realised and (iii) competing technologies (in particular natural gas)[3] are advancing their position.

The paper is structured as follows. Section 2 contains a description of the technology and the technical context in which it is situated. The analytical framework—an 'innovation system approach'—is outlined in Section 3, whereas Section 4 focuses on the empirical analysis of the evolution of the innovation system. Section 5 identifies three policy challenges and the Section 6 contains a summary and a concluding discussion.

2. Biomass combined heat and power—the technology and its potential

Conventional combined heat and power generation involves burning a solid fuel using the flue gases to produce steam, and passing steam through a steam turbine that produces electricity (steam cycle). The remaining heat is then used in either a district heating system or for industrial purposes in the form of process steam.[4] In the Swedish context, the potential diffusion of biomass CHP is closely related to the extensive use of district heating and to the huge paper and pulp industry with its need for process steam (SOU 2001:77; Energimyndigheten, 2005a). Up until recently, the hot water used in both district heating and for producing industrial process heat were largely generated in boilers that were not linked to steam turbines. This can mainly be explained by the massive build-up of nuclear capacity in the 1980s, which led to very low power prices (Kåberger, 2002).[5] Nuclear power dominates power production in Sweden together with large-scale hydro power, both having low marginal costs. With an abundant supply, power was for long very cheap and these low power prices discouraged not only CHP production but also investment in condense power production based on biomass.

Table 1
Input of bioenergy in industry and into district heating in Sweden, in TWh energy supplied

	Bioenergy input, total		Bioenergy input for power production	
	District heating	Industry	District heating	Industry
1980	2.3	35.2	0	0.7
1995	21.0	49.1	1.0	2.1
2004	32.9	52.6	5.6	4.7

Source: Energimyndigheten (2005, Tables 12, 15 and 36).

The district heating system is not only very large but it grew from 34.5 TWh of heat delivered in 1980 to 53.5 TWh of heat delivered in 2004, enlarging the potential for CHP production (Energimyndigheten, 2005a, Table 26). Parallel to this growth, there has been an increase in the use of biomass as source of energy in district heating. In 2004, as much as 32.9 TWh[6] of bio energy was used in that application—up from 2.3 TWh in 1980, see Table 1. In addition, industry used 52 TWh of bio energy in 2004, up from 35 TWh in 1980.[7] Hence, there has been a very pronounced shift towards biomass as a source of energy in district heating as well as for generating industrial process steam. This implies that the potential for biomass CHP production has expanded greatly.

The use of bio energy for electricity production was, however, very modest until very recently. In district heating, the use of bio energy for that purpose amounted to 1 TWh in 1995, see Table 1. It began to rise in 2003 and 2004 only, after the introduction of tradable green certificates, see more below. In industry, the use of bio energy for the production of power has been slightly less modest (2.1 TWh in 1995) and also here it rose somewhat in 2004. Compared with the very sizeable and growing use of biomass in district heating and in industry, the level of biopower production has, thus, been of marginal nature, revealing a large underused potential. Indeed, the production of power from biomass is seen largely as a by-product of an extensive heat generation using biomass as the primary source of energy.

The precise potential of biopower has been subject of a number of studies (e.g. SOU, 1991:93, 2005:33; Knutsson and Werner, 2002; Elforsk, 2003) and the figures mentioned vary a great deal. Some have a relatively short-term focus and they stress, therefore, a number of obvious limiting factors. Among these, we can note supply restrictions in the equipment industry and weak economic

[3]Waste is increasingly used as fuel and it encroaches on the market for biopower. As the power to heat ratio is lower from waste, this reduces the potential production of biopower. For reasons of space, we will not, however, deal with this issue.

[4]In a more advanced variant, a gaseous fuel is used that is incinerated in a gas turbine to produce electricity. The energy in the remaining flue gases is recovered in a steam turbine (combined cycle). With gasification, a combined cycle can be used also for solid fuels, the benefit of which is that the power-to-heat ratio may be increased compared to that in the steam cycle (SOU, 1995:139; Energimyndigheten, 2005a).

[5]Indeed, CHP production, using all types of fuel, has been quite modest, in fact very underdeveloped (SOU, 2005:33). Production of power amounted to 5.6 TWh in 1980. An expansion of nuclear power then led to a reduction in CHP production and it was not until 1994 that the same level was reached. By 2004, the supply had grown to 7.5 TWh (Energimyndigheten, 2005a, Tables 18 and 22).

[6]To this can be added 7.2 TWh of waste.

[7]Most of this is used in the paper and pulp industry (Energimyndigheten, 2005a, Table 35).