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Research paper

Keep that fire burning: Fuel supply risk management strategies of Swedish district heating plants and implications for energy security

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ABSTRACT

Recent decades have seen a strong increase in bioenergy utilization in Sweden, from 52 TWh in 1983 to 128 TWh in 2013. Much of this increase has been achieved by replacing fossil fuels with different forms of bioenergy in district heating. Increased use of bioenergy is generally seen as key to reducing fossil fuel consumption and greenhouse gas emissions and improving energy security.

However, replacing fossil fuels with solid biomass fuels in stationary heat and power generation entails significantly more complicated fuel supply logistics, with geographically scattered material associated with storage difficulties and low energy density. Given these risks and challenges and the key role of biomass-based district heating in the Swedish energy system, disturbances in fuel supply to district heating could potentially be an energy security issue.

Through literature studies and interviews with employees at 18 district heating plants, we mapped present and future risks and risk management strategies in district heating supply in the Mälardalen region, south-east Sweden. We found that although small disturbances to fuel supply are not uncommon, the likelihood of heat supply failures due to fuel supply problems is low. Risk awareness is generally high among fuel supply managers, with widespread use of multilevel redundancies and diversification as key risk management strategies. However, fuel supply to plants is highly dependent on functioning truck transport and, consequently, availability of diesel fuel for trucks. Risk management can be strengthened further by implementation of forward-looking risk assessments that are less reliant on past experiences.

1. Introduction

1.1. The role of bioenergy-based district heating in the Swedish energy system

The cold Swedish climate means that heating is a vital energy service, comprising about 360 PJ or more than 25% of total Swedish energy consumption [1]. District heating (DH) is the most common form of space heating in Sweden, providing 72% of the heat used in non-residential buildings, 83% in multi-dwelling buildings and 12% in one- or two-dwelling buildings [2].

Until the 1970s, fuel supply in DH was almost exclusively based on heating oil, but concerns about excessive dependence on imported fossil fuels following the oil crises in 1973–74 and 1979–80 initiated a widespread fuel shift away from petroleum-based fuels [3]. By the early 1980s, coal and peat comprised significant shares of fuel supply. With increasing focus on environmental issues in general and climate change in particular, DH fuel supply from the late 1980s onwards has come to be dominated by different forms of woody biomass and municipal solid waste. An overview of the composition of DH fuel input from 1980 to 2014 can be seen in Fig. 1.

Incentives in the form of investment subsidies in the 1980s and CO_2 taxes from the early 1990s accelerated this transition from fossil fuels to bioenergy [4].

1.2. Study objective and research questions

Despite growing societal concerns about energy security, especially energy security of supply, research in this field has tended to only rarely investigate bioenergy in any detail. In general bioenergy tends to be seen as more “secure” than fossil fuels in transportation

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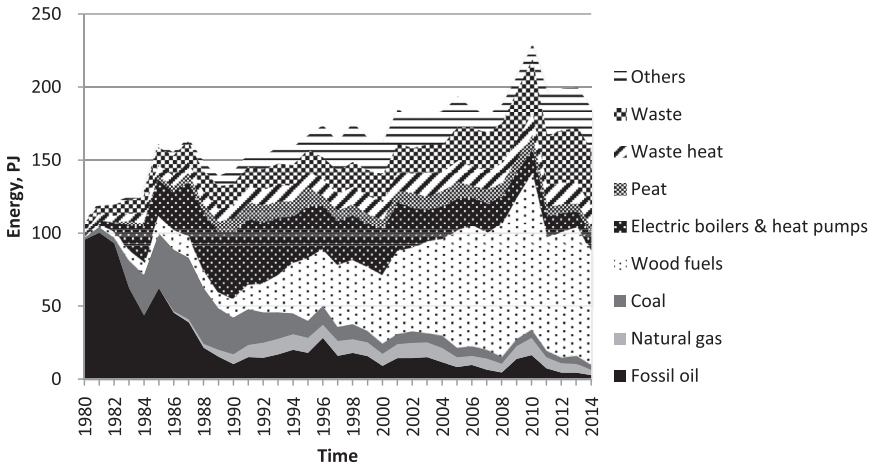

Fig. 1. Fuels used in Swedish district heating 1980–2014. Data source: Swedish District Heating Association.

as well as in the heat & power sector [5,6], largely based on the fact that biomass resources are significantly more widely geographically dispersed on a global basis than crude oil and natural gas.

However, bioenergy-based district heating systems have certain characteristics with potentially negative implications for societal energy security of supply. Biomass fuels are bulky and difficult to store, with the implication that onsite fuel inventory is limited and fuels have to be delivered continuously. In addition, since district heating systems in most cases are run as local monopolies, heat provision of a large number of citizens is the responsibility of a single economic actor, in effect creating an overlap between energy security of a town and the supply chain risk management strategies of an individual company.

Our objective in this study is to investigate the fuel supply chain risk management strategies among Swedish district heating systems, and the consequences this might have for energy security. We focus on the region around Lake Mälaren in South-East Sweden, which includes Stockholm and its suburbs as well as several other important Swedish cities. We use empirical data collected through semi-structured interviews with individuals responsible for fuel supply at 18 DH companies in the region. The interviews are analyzed using theories from the supply chain risk management (SCRM) literature with focus on the interaction between SCRM and energy security.

2. Methods and materials

2.1. Theoretical framework

2.1.1. Energy security

Since the oil crises of the 1970's, *energy security* has been a commonly discussed issue on the political agenda on a global, European and Swedish level. Despite this, there is no commonly acknowledged definition of what energy security actually entails. Originally, discussions on energy security were very much centered on security of energy supply, and specifically on societal vulnerabilities from excessive dependence on imported fossil fuels [7].

Over time however, the energy security concept has been broadened to include a host of other issues in addition to security of supply. These include, but are not limited to, security of demand, public acceptance of energy generation technologies, economic efficiency and sustainability aspects [8,9]. The broadening of the concept is to a certain extent justified as "security" itself is a partly subjective notion [10], but the proliferation of definitions has led to a considerable degree of confusion [11].

A 2012 review of the energy security literature [9] found that *continuity of energy supply* is the one common theme that is present in all definitions of energy security. Based on this and the fact that most other aspects that have been attached to "energy security" already are included in other well-established fields of research, the author argued that the term "energy security" should be restricted for discussions on the continuity of energy supply. We agree with this conclusion and thus the focus herein is on the actual continuity of fuel supply flows. However, it is important to further clarify that energy security of supply can be both a matter of long-term availability of a resource - due e.g. to gradual depletion of fossil fuel resources - or short-term accessibility threatened by temporary disruptions in supply chain [8,11]. Our focus here is on the latter.

2.1.2. Overlap between energy security and supply chain risk management in district heating systems

Although energy security is an issue of general societal relevance, a large portion of the responsibility for ensuring continuous supply of energy services is borne by energy market actors [12]. Swedish district heating systems present an especially interesting case in this perspective because they tend – in contrast to electrical power systems or natural gas grids – to be geographically restricted to a single town or city area. District heating systems in Sweden are predominantly owned and run as regional monopolies by a single economic actor (most commonly municipally-owned companies though with important exceptions in the form of large energy companies – Vattenfall, EON, Fortum – or other private actors) [13]. This means that supply chain disruptions at the company level can have serious consequences for heat supply of large urban areas. As a consequence, district heating systems entail a close connection between society-level energy security of supply and company-level *supply chain risk management*.

Supply chain risk management (SCRM) has attracted much interest in recent years, as the global economy is undergoing significant changes, and where three parallel developments are of particular importance for supply chain management. *To begin with*, internationalization of markets for goods and services has meant that supply chains have become longer in a strictly geographical sense. *Secondly*, specialization of individual supply chain functions means that a larger number of individual firms are involved. *Thirdly*, many companies are striving to reduce costs of inventory, which has led to heavy reliance on just-in-time deliveries of raw materials and components [14].

Supply chains in the 21st century are thus often international or intercontinental, involve many different individual actors and rely