Energy 106 (2016) 45–53

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

System impact of energy efficient building refurbishment within a district heated region

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ARTICLE INFO

Article history:
Received 2 November 2015
Received in revised form
19 February 2016
Accepted 9 March 2016
Available online 31 March 2016

Keywords:
Energy efficiency
District heating system
Refurbishment
Simulation
Greenhouse gases
Buildings

ABSTRACT

The energy efficiency of the European building stock needs to be increased in order to fulfill the climate goals of the European Union. To be able to evaluate the impact of energy efficient refurbishment in matters of greenhouse gas emissions, it is necessary to apply a system perspective where not only the building but also the surrounding energy system is taken into consideration.

This study examines the impact that energy efficient refurbishment of multi-family buildings has on the district heating and the electricity production. It also investigates the impact on electricity utilization and emissions of greenhouse gases.

The results from the simulation of four energy efficiency building refurbishment packages were used to evaluate the impact on the district heating system. The packages were chosen to show the difference between refurbishment actions that increase the use of electricity when lowering the heat demand, and actions that lower the heat demand without increasing the electricity use. The energy system cost optimization modeling tool MODEST (Model for Optimization of Dynamic Energy Systems with Time-Dependent Components and Boundary Conditions) was used.

When comparing two refurbishment packages with the same annual district heating use, this study shows that a package including changes in the building envelope decreases the greenhouse gas emissions more than a package including ventilation measures.

1. Introduction

The European Council endorsed a goal regarding all member states of the European Union in which GHG (greenhouse gas) emissions within the union should be reduced by 40% by the year 2030 compared with 1990 [1]. In connection with this goal there is also a goal to increase the share of renewable energy to be at least 27% in the year 2030 and to increase energy efficiency by 27%–2030 in terms of supplied energy, compared to a prognosis without policy instruments. The prognosis is from Primes [2].

The Swedish housing and service sector uses 40% of the total national energy use and 65% of this is for space heating and domestic hot water in the buildings [3]. To be able to fulfill the goals of the European Union, the energy needed for space heating as well as domestic hot water has to be reduced, and more efficient use of energy is required. In Sweden 92% of the energy used for space heating and domestic hot water in multi-family buildings is based on DH (district heating) [4]. It is therefore probable that urban areas supplied by DH will also be targets for improving energy efficiency and this, in turn, will most likely also influence the supply plants and distribution networks of the DHS (district heating systems). Many DHS in Sweden today include CHP (combined heat and power) plants with a potential for further expansion of electricity production within the DHS as well [5]. In systems like these the production of electricity will be influenced when the heat demand changes. If the heat demand changes and less or more DH is produced, this will influence the amount of fuel needed in the plant. When a change in the amount of burned fuel occurs, this will also change the amount of emitted GHG emissions locally in an amount which also depend of what sort of fuel that is used.

From a wider perspective, it can be assumed that if electricity is not produced in the CHP plants, it has to be produced somewhere

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http://dx.doi.org/10.1016/j.energy.2016.03.043
0360-5442/

Abbreviations

BER	Building envelope refurbishment
CCP	Coal condensing power
CHP	Combined heat and power
CO_2 eq	Carbon dioxide equivalent
DC	District cooling
DEER	Deep energy efficiency refurbishment
DH	District heating
DHS	District heating system
FGC	Flue gas condensation
GHG	Greenhouse gases
HRV	Heat Recovery Ventilation
HRV-D	HRV decreased indoor temperature
HRV-O	HRV original setup
LPG	Liquefied petroleum gas

else in the electricity system to meet the demand. As CCP (coal-fired condensing power) plants have the highest variable cost, they work as the operational marginal source of electricity in Europe in a short term perspective. Considering a fully deregulated electricity market, this will also be valid for Sweden [6]. When changes occur in the electricity system it is therefore assumed to influence the electricity production on the marginal. The CCP plants also emits the highest levels of GHG emissions among electricity producing units in Europe per produced unit of electricity [7].

In Sweden, about 40% of the DH is based on biofuels [8]. Considering that biomass is a limited resource, all potential savings of biomass in the studied system can be assumed to be used in another energy system with limited access to it. This is also discussed by Wetterlund et al. [9,10], and Grönkvist et al. deals with this approach in a study regarding GHG emissions from DH technologies [11]. As CCP is the operational marginal source of electricity, biomass which is not required for heating can be used for electricity production and thus assumed to replace coal [12,13].

1.1. State of the art

There are several examples of previous studies covering each part of this study; energy performance of building refurbishment as well as DHS optimization and the climate impact of GHG. However, there are quite few studies that have been made from a wider system perspective in this area, combining both energy efficient refurbishment packages as well as their impact on the DHS and the global GHG emissions. Some earlier studies with this kind of system perspective were made, showing different impacts on the DHS depending on the choice of refurbishment strategies [14–17]. In common for these studies is that they indicate that not all energy efficient measures leads to decreased GHG emissions or less primary energy savings. An important result from these studies is the interaction between the DH demand and the electricity production in CHP units, where refurbishment measures influence the production of cogenerated electricity.

Within the research area there is however a need for more in depth analyses on how different energy efficiency refurbishment measures in different types of buildings influence the heat demand and thereby the DHS. This is also mentioned by Åberg [18], who specifically points out the need for refined building simulations in studies with a system perspective. Taking this into consideration, this study complements previous studies by using a validated building model in which packages of refurbishment measures are simulated. This study also investigates further the relation between energy efficient refurbishment within the DHS and how it influences the GHG emissions.

1.2. Objective

This study examines how energy efficient refurbishment of a multi-family housing area in the municipality of Borlänge, Sweden, can influence DH production and utilization, the local electricity production and utilization, as well as impact on global GHG emissions. The study also takes into consideration the use of biomass in the local DH production and the possibility for saved biomass to be used as a replacement for fossil fuel.

Four different building refurbishment packages were simulated on a case study building and the results were part of input data in a DHS model. It was essential for this study that these packages should mainly be chosen to show the difference between refurbishment actions that increase the use of electricity when lowering the heat demand in the building, and actions that lower the heat demand without increasing the electricity use.

The objective of this study is to evaluate the impact that the different refurbishment packages have on the DHS, and also how they differ from each other when applying an energy system perspective at a municipal level. The municipal level means that DH and electricity production, distribution and use within the municipality are included in the study. The aim is therefore to combine building refurbishment studies with DHS studies to further link these closely related disciplines. The local prerequisites are described and the results of the analysis are presented.

2. Case study description

This study was performed for the municipality of Borlänge, situated 250 km North West of Stockholm, Sweden. The municipality of Borlänge has approximately 50,000 inhabitants and within the urban area DH is the dominating way of supplying heat to larger buildings such as multi-family buildings and commercial buildings. The DH network is connected to the municipality of Falun, 20 km away. Falun is about the same size as Borlänge in both area and population but the number of buildings connected to DH is slightly smaller. A DH pipeline with a capacity of 30 MW connects the cities and gives both cities the possibility of supplying the other. The pipeline was taken into operation during 2014 and is jointly owned by the energy companies in Borlänge and Falun. Fig. 1 shows a schematic view of the DHS in Borlänge and Falun. For 2013 the delivered DH in Borlänge was 370 GWh and in Falun 330 GWh [8].

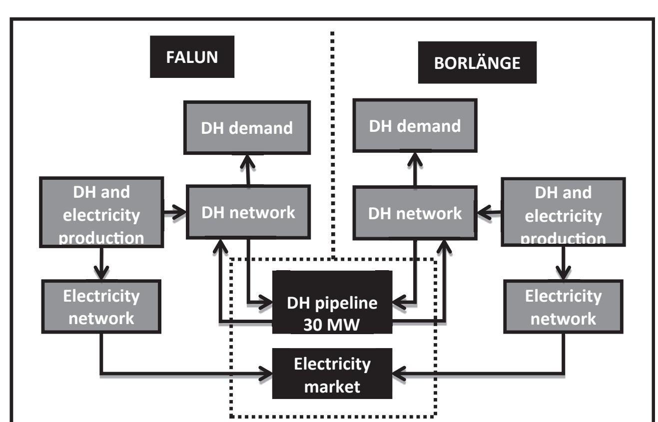

Fig. 1. Schematic view of the common DHS of Borlänge and Falun.