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Using industrial and commercial waste heat for residential heat supply: A case study from Hamburg, Germany

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ABSTRACT

Residential heat accounts for a large share of final energy consumption in European countries. Hence it offers a large CO_2 savings potential: either through reducing heat demand by energy-efficiency retrofitting of buildings or by substituting CO_2 intensive heating fuels. Industrial and commercial waste heat could be one such substitute. Using it for residential heating purposes could postpone or even avoid the costly energy-efficiency refurbishing of the building stock. Urban areas differ in their potential for using waste heat in residential space and water heating, depending not only on supply and demand of heat in the aggregate, but also on the makeup of the building stock, waste heat temperature levels and their spatial distribution. Case studies of real-world neighborhoods will help us understand these relationships. The work presented here offers such a case study for Lokstedt, a rather typical neighborhood in the North German city of Hamburg. Residential heat demand in Lokstedt was estimated based on building age, floor space and volume. The potential of industrial and commercial waste heat supply was estimated with data collection from companies in the neighborhood, combined with waste heat characteristics for different sectors taken from literature. We estimated a heat demand of 12.8 GWh/a for the area and a waste heat potential of 0.47–0.93 GWh/a. The available waste heat could, in theory cover about 5% of residential heat demand, accounting for the heat demand that could be saved within 8 years of refurbishing the building stock at the current rate.

1. Introduction

It is a declared national German policy goal to reduce nationwide CO_2 emissions by 80% until 2050, against the base year 1990. According to a recent study, about 60% of that reduction has to come from the building sector (Arbeitsgemeinschaft Prognos AG/Öko-Institut, 2009), whose final energy use is dominated by space heating (in 2008 72% of the final energy consumption of German households (Ziesing et al., 2008)). One option for reducing CO_2 emissions from heating is the usage of waste heat from industrial and commercial operations.

There are a number of companies aiming to use waste heat in ORC-processes, for pool heating, in adsorption storages and other applications. But how big is the potential for waste heat to serve residential heating demand? As the use of waste heat for residential space heating depends on a number of location-specific factors (proximity of heat source and sink, temperature levels and so on), the answer to this question profits from case studies exploring the coincidence of these factors in a real-world case.

This is what the study presented here set out to do. Its aim was to find out whether, in a specific mixed-use neighborhood, industrial and commercial excess heat and residential heating demand are in the same order of magnitude and whether further investigations are therefore called for. Heat demand was estimated based on building age, floor space and geometry. The potential of industrial and commercial waste heat supply was estimated with data collection from companies in the neighborhood, combined with waste heat characteristics for different sectors taken from literature. Because this being a first shot at estimating the heat flows in the area, temperature levels and transport losses were not considered.

2. Description of waste heat usage

McKenna and Normann (2010) found the potential of industrial excess heat in Great Britain to be between 10 and 20 TWh/a, the

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biggest share of which is found in the iron and steel, chemicals, aluminum and non-metallic mineral industries, at 100–500 °C. Bonilla, Blanco, Lopez, and Sala (1997) estimated the potential for Basque country to be 14 TWh/a. Glatzel (2001) approximated the industrial excess heat potential for Germany in 2001 to be 278 TWh/a, compared to a total final energy demand of 2.420 TWh/a in 2009 (Arbeitsgemeinschaft Energiebilanzen, 2010). It may seem surprising that according to these studies, the waste heat potential of Germany should be ten times higher than e.g. the potential of Great Britain. The reason for these greatly differing results lies in the methods used. Glatzel did a rough estimation, considering waste heat potential to be 40% of the input energy, while McKenna and Normann as well as Bonilla et al. considered different sectors individually at different temperature levels. All of these numbers are rather general and focus on entire countries or regions respectively.

For Germany, there are two studies focusing on towns: In "Wärmeatlas Baden-Württemberg" (Arbeitsgemeinschaft Energiebilanzen, 2010; Blesl et al., 2008) the industrial waste heat potentials for four different cities are presented (Heilbronn 10 GWh/a, Rottweil 14 GWh/a, Schwendi 5 GWh/a, Mauenheim none (0 GWh/a)). However, these estimates are based on the experience of the researchers and therefore not verifiable or transferable. Another study, the Herakles Project (Drath, 2002), looked at the city of Duisburg, adopting a bottom-up approach to gain operational figures about waste heat for different sectors. Although the used database was at city level, the waste heat potential was only published at state level. Nevertheless, the work presented here follows a similar approach, using the operational figures from the Herakles project to estimate the waste heat potential of industries at a city level. Furthermore, the geographic correlation between heat sinks and sources are considered in this work.

3. Investigated area

Hamburg is situated in the north of Germany, where the summers are cool (daily maximum average temperature of 16.8 °C) and the winter is mild (average 0.5–1.1 °C) (DIN, 2003). For this study the housing stock of 11 blocks within the Lokstedt neighborhood was considered, not including office buildings and schools. Other non-residential buildings which are irrelevant to heat demand were also excluded. Lokstedt is a neighborhood with 25,000 inhabitants in the Hamburg District of Eimsbüttel. The investigated area consists of the gray shaded blocks in Fig. 1.

There is no heavy industry in this area, nor are there big factories. It is dominated by residential housing and small to medium sized commercial establishments. It is a typical living area for Germany, as it can be found in many places elsewhere. The make-up of Lokstedt may be considered somewhere in the middle between an entirely residential area, where there is no industrial or commercial waste heat nearby, and an area neighboring heavy industry like for example Hamburg-Heimfeld or Hamburg-Wilhelmsburg with an petroleum refinery and a food oil producer within a distance of 500 m and less to residential multi-family houses.

4. Methods and results

4.1. Heat demand

In the German microcensus (Mikrozensus - Zusatzerhebung, 2006), data concerning the owner, the age, the size of the buildings and its usage (residential, commercial, etc.) is collected. However, data protection rules in Germany are very strict. Thus, this data is not published. Therefore, it is necessary to estimate the heat demand with auxiliary information from other sources. This work used a data set constructed by a local engineering office: sumbi. Each building was viewed by energy experts and its shape, area, age and heat demand estimated, the latter using the method of the IWU institute in Darmstadt (Loga, Diefenbach, Knissel, & Born, 2011) who developed Germany's most authoritative building typology. This led to a data set of 112 buildings with estimated building age, type, number of units, floors and an approximated heat demand (kWh/m^2 a). However, these demands are only standard values or approximations respectively. According to Stein (Stein, 2011) the energy consumption in a building differs by up to 51% due to the behavior of the inhabitants. But this effect is averaged by summarizing the heat demand of multiple houses and thus inhabitants (Gruber et al., 2005).

In the considered area in Lokstedt, most buildings (62.5%) date from the construction period 1949–1978, followed by 28.6% of the buildings dating from 1979 to 1990. There are neither very old buildings (<1918) nor modern (>2001). 19.6% of the buildings have more than 13 units and 34.8% are one or two family houses built before the 1990th. Thus, the total residential heat demand in the investigated area is estimated to be 12.8 GWh/a.

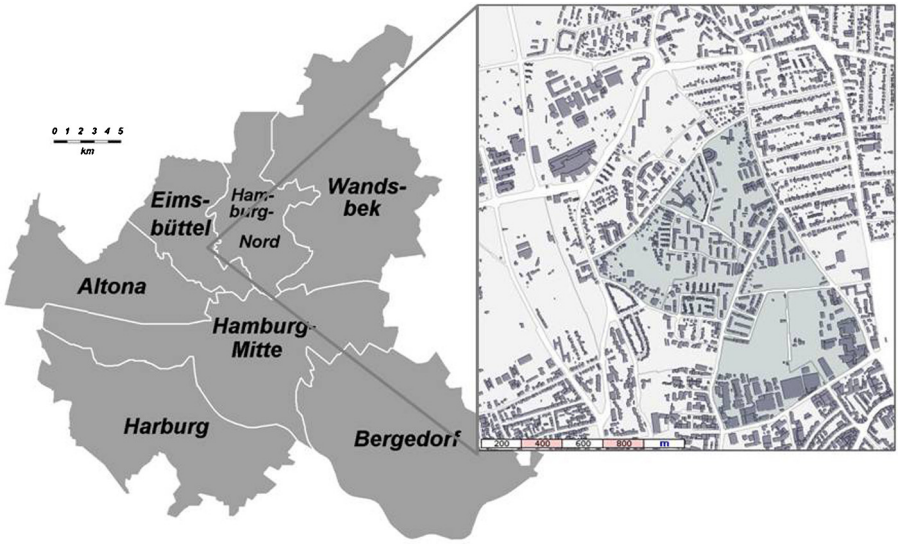

Fig. 1. Investigated area (gray) in Lokstedt, Hamburg.

Based on figure from Wikipedia Germany (2011).