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Enviromental Implications of Växjö Municipality's Energy Requirement for New Residential Buildings

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Abstract

The Växjö Municipality in Sweden sets specific energy requirements above the national building code while selling land for new residential buildings. A main energy requirement for Östra Lugnet residential area in Växjö was that all buildings must be connected to the district heating network. In this paper we analysed final energy use of the buildings, and compared the primary energy use and CO_2 emission from operation of the buildings connected to district heating system with hypothetical scenarios where only air-source heat pumps were installed. The result showed that district heating is the better option from the perspective of lower carbon emission. Therefore, it seems appropriate for Växjö Municipality to set conditions for new residential buildings in Östra Lugnet to connect to the local district heating network as it contributes to its goal of low carbon society.

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Keywords: Energy requirement; district heating; heat pump; residential buildings

Introduction

Växjö municipality has a goal to be fossil fuel free by 2030. It imposes specific energy requirements beyond the Swedish building code while selling plots for new residential buildings. In the Östra Lugnet new residential area Växjö municipality sold plots to private persons to build detached houses and to companies to build prototype detached or row houses (called as "group/row houses" in Sweden) that were finally sold to the private persons. A condition attached while selling the plots was that the new buildings must be connected to the municipality-owned local biomass-based district heating system that produces both heat and electricity. In the group/row houses installation of air-source heat pumps was not allowed and the maximum specific energy use was set to be 100 kWh/m^{2}A$_{temp}$/year compared to the 110 kWh/m^{2}A$_{temp}$/year in the then prevailing Swedish building code BBR 2009. As such there are three different types of residential buildings in Östra Lugnet (see Table 1); privately-built detached houses with

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district heating only, privately-built detached houses with district heating and air-source heat pump (henceforth “detached houses with air-source heat pump”), and company-built group/row houses with district heating only. The companies GBJ bygg, Kärnhem and Myresjöhus built the group/row houses in five quarters.

The aim of this paper is (a) to analyse if the buildings meet the specific energy use requirements, and (b) to analyse the environmental implications of the requirement that the buildings must be connected to district heating system. To contribute to the second objective we estimate the primary energy use and CO_2 emission of operating the buildings with the existing district heating system and compare with a scenario where the buildings were heated with only air-source heat pumps. Our study is based on actual energy use of the buildings in comparison to similar studies based on simulated energy demand of buildings.

Method

Data on electricity use and energy use for space heating and hot water purposes (henceforth, “heating”) of the buildings for the year 2012 was collected from the local energy utility. Heating energy use was adjusted to a normal year. All buildings were assumed to have mechanical exhaust- and supply (FT) ventilation system and electricity use to operate the FT-system was assumed to be 8 kWh/m^2A_{temp}/year [1]. Electricity use to operate air-source heat pumps was estimated as Eq. 1 assuming that the household electricity use in these buildings is same as the average in houses with only district heating system. The Coefficient of Performance (COP) factor of the air-source heat pumps was assumed to range from 2 to 3.33 [4].

*Electricity use to operate air-source heat pump = Metered electricity use − average household electricity use of [privately-built detached houses and group/row] houses with district heating only − electricity use for ventilation……*Eq. 1.

Specific energy use, which is the purchased energy for space heating and hot water and electricity to operate (e.g. for ventilation and heat pump) the building excluding for household purposes, is calculated as follows.

*Specific energy use of buildings with district heating only = Delivered district heat + assumed electricity use for ventilation …*Eq. 2

*Specific energy use of buildings with air-source heat pump = Delivered district heat + assumed electricity use for ventilation + electricity use to operate air-source heat pump ……*Eq. 3.

Final energy demand is the total energy required including e.g. heat retrieved by heat pumps from air or ground to operate a building, and it is calculated as follows.

Final energy demand of buildings with district heating only (including group/row houses) *= Delivered district heat*(100 – 5% heat loss at heat exchanger) + assumed electricity use for ventilation system……*Eq. 4.

Final energy demand of buildings with district heating and air-source heat pump = Delivered district heat(100 – 5% heat loss at heat exchanger) + assumed electricity use for ventilation + electricity use to operate air-source heat pump*COP factor……*Eq. 5.

Primary energy use and CO_2 emission of the houses were calculated from the estimated final energy demand. A system-wide perspective was applied and all stages from extraction of raw material to final energy use were included. Following [2] we assumed that the co-generated electricity from the district heating plant replaces electricity produced in a coal-fired condensing plant with a conversion efficiency of 47% [3]. The details of district heating system are that of the district heating plant in Växjö. Net CO_2 emission from the forest biomass used in the district heating system is assumed to be zero [5]. The distribution losses in district heat and electricity supply were assumed be 13% [6] and 7% respectively [3]. The fuel cycle losses were assumed to be 1%, 5.5% and 10% for biomass, oil and coal, respectively [7]. Primary energy use was calculated separately for the building's electricity (for ventilation and heat pump) and heating use, and for specific fuel input. The primary energy values obtained for each type of fuel input were then added to obtain the total primary energy use of a building. The primary energy value of each fuel input was multiplied with its carbon content and the sum of such values for all fuels is the CO_2 emission from a building.

Results

There were large variations in (normalized) specific energy use in each category of houses (Table 1). The variation was largest among the houses with air-source heat pump (31 - 157 kWh/m^{2}A$_{temp}$/year), even with same heated area (31 - 71 kWh/m^{2}A$_{temp}$/year among houses with an A$_{temp}$ of 165 m^2). There was less variation among the houses with only district heating system, but the average specific energy use was higher. The average specific energy use was highest for the company-built group/row houses, especially in some quarters. Also a higher proportion of these houses did not fulfill the specific energy use requirements of BBR 2009 (60%) or of Växjö municipality (78%).

Table 1: Average specific energy use of different category of houses and the percentages that did not fulfill the energy requirements

Type of buildings/owners (n = No. of buildings)	Specific energy use [kWh/m^{2}A$_{temp}$/year]		% of house that didn't fulfill the specific energy use requirement	
	Average	Range	BBR 2009 (110 kWh/m^{2}A$_{temp}$/year)	Växjö municipality (100 kWh/m^{2}A$_{temp}$/year)
Detached houses with air-source heat pump (n=58)	75.6	31.5 – 157.2	7	Not applicable
Detached houses with district heating only (n=49)	87.8	60.4 – 145.2	6	Not applicable
Group/row houses with district heating only (n=74)	98.0	63.4 – 145.4	27	38
GBJ bygg				
(quarter)Galaxen (n=5)	87.5	69.8 – 105.1	0	20
(quarter)Kosmos (n=12)	97.7	77.1 – 119.5	17	42
Kärnhem				
(quarter)Rymden (n=25)	87.3	63.4 – 123.6	4	4
(quarter)Pluto (n=23)	113.1	91.6 – 145.4	60	78
Myresjöhus				
(quarter)Miranda (n=9)	95.4	63.8 – 113.8	33	44

The average specific energy use was lowest, but the average final energy demand, primary energy use and CO_2 emission were highest for houses with air-source heat pump (Figure 1). The average primary energy use was lowest for houses with district heating only, while average net CO_2 emission was most negative for group/row houses. A negative net CO_2 emission means that the co-produced electricity from the biomass-based district heating system replaces the same amount of electricity generated in a carbon intensive coal-fired power plant elsewhere.

Figure 2 shows the average specific energy use, average primary energy use and average CO_2 emission, if all the studied buildings had only district heating system or air-source heat pumps. The results for heat pumps varied depending on the COP-factor and are reflected in the error bars. The lower end is for a higher COP-factor and vice-versa. If all the buildings had only biomass-based district heating system then the specific energy use would be highest, but primary energy use and CO_2 emission would be lowest. The result would be opposite if the houses had only air-source heat pump.

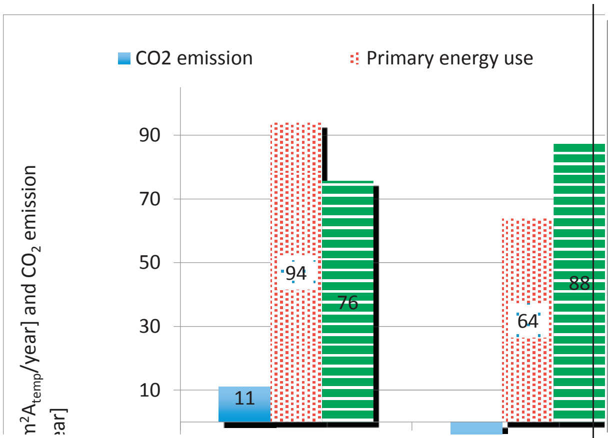

Figure 1: Average specific energy use, primary energy use, CO_2 emission of different categories of houses in Östra Lugnet

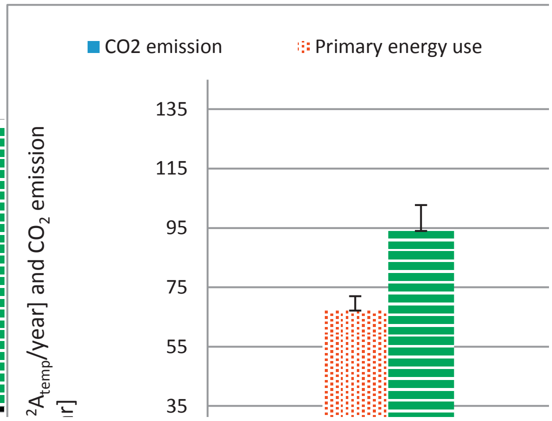

Figure 2: Average specific energy use, primary energy use, CO_2 emissions, if all houses had a particular heating system. Error bars show the range considering the COP factor of heat pumps.

Conclusions

The average specific energy use was highest for group/row houses and a higher proportion of them compared to other categories of houses do not meet the energy requirements of BBR or of Växjö municipality. There were large variations in specific energy use among houses in each category, even those built by the same company. Such variations could be due to varying floor area, varying COP factor and use duration of air-source heat pumps, or that the companies have erected buildings of different energy standards to target different consumer categories. The variations among houses of same size, located in same quarter and built by same company could be due to varying household size, composition or behavior. In general, the privately-built houses have a better energy performance probably because they were built energy efficient to reduce the operational energy use.

Swedish building regulation requires buildings to fulfill the specific energy use criterion, but this is not an appropriate indicator of environmental performance of a building. Houses with a higher specific energy use e.g. those with district heating system can have lower primary energy use and CO_2 emissions than a house with lower specific energy use e.g. one with air-source heat pump. From this perspective it seems appropriate that Växjö municipality demands the houses be connected to the district heating network.

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Biography

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