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Evaluation of a Single Family Low Energy Building in Cold Climate

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Abstract

Verification of energy performance and indoor climate by detailed field measurements in buildings is of great importance and promotes an assurance in the process of constructing low energy buildings and enables to utilize the full potential of energy efficiency measures.

In the present work a single family building with a heated living space area of 175 m^2 has been monitored. The heating system has a wood pellet stove for space heating (SH) and domestic hot water (DHW) and on the roof there are solar collectors in a southerly direction contributing to SH and DHW. SH is distributed by the ventilation system and an under floor heating system which is connected to a heat storage water tank. The incoming outdoor air is pre-heated in an earth-to-air heat exchanger and the building has a measured specific energy usage of 54 kWh/m^2year which is far lower than today's regulation at 130 kWh/m^2year in the actual climate zone. The low energy use in the building are due to thick thermal insulation (average U_m = 0.18 W/°C m^2), an air tight envelope (q_{50} = 0.165 l/sm^2), heat recovery of exhaust air (average 74 % efficiency) and free heat from the ground pre-heating of supply air which is above 2°C even for outdoor temperatures down to -27°C. An essential factor was the low rate of air changes during the heating season about 40 % of the regulated requirement. Measurements of indoor air quality like carbon dioxide occasionally indicated insufficient ventilation.

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Keywords: Energy efficient building; integrated heating system; eart-to-air heat exchanger; indoor air carbon dioxide

1. Introduction

As part of making the society more energy efficient it is of great importance to measure, investigate and improve the energy performance in buildings. This study focus on measurements in a low-energy building which during heating season has a lower fan controlled air changes per hour than the demand according to [1]. The consequence of that on

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the indoor air quality in terms of CO_2-concentration and relative humidity are reported on in this study. The building has a heating system based on a wood pellets stove, solar collectors and an earth-to-air heat exchanger (EAHE) for pre-heating the inlet supply air. Application of an EAHE is not unique it has been used long time ago [2] mainly for cooling, however more recently there are a number of studies [3, 4] adopted to improve the technique.

Nomenclature

A_{temp}	heated floor area above 10ºC
U_m	overall average heat transfer coefficient, W/m^2 ºC
A_E	area of building envelope towards outdoor air, m^2
A	area of a building component, m^2
ρ	density of air, kg/m^3
C_p	specific heat capacity of air, J/kgºC
q_S	fan controlled inlet supply air flow, m^3/s
η	heat exchanger inlet air temperature efficiency
q_L	air flow leakage based on air tightness measurement, m^3/s
P_L	total heat losses in the building, W
P_S	diurnal measured space heating, kWh
K	linear regression coefficient, kWh/ºC
m	linear regression constant, kWh
T_i	Indoor air dry bulb temperature, ºC
T_o	Outdoor air dry bulb temperature, ºC
q_{50}	leakage air flow at 50 Pa pressure difference, liter/s and m^2

1.1. Specifications of the building

The building in this work is situated in the vicinity of Umeå, latitude N 63º 50' and longitude E 20º 14'. The A_{temp} of the building is 175 m^2, distributed on a ground floor and an open attic space. The surface of the envelope towards outdoor air is 325.2 m^2 and the total ventilated indoor air volume is 498.2 m^3. During the period of evaluation the house has been inhabited by two adults. The building has a ridge roof and an exterior façade made of wood panel. The heating system includes a wood pellet stove for SH and DHW. According to the manufacturer the pellet stove provides 85 to 90 percent of its useful heat via the water circulation system to the heat storage tank. The performed measurements on the pellet stove concerned the heat released by the water circulation to the heat storage tank, which has a volume of 0.75 m^3. On the roof of the house there are 7.08 m^2 of solar collectors installed in a southerly direction. According to the manufacturer the annual output of heat from the solar collectors could be expected to be 3 606 kWh. SH is distributed by a under floor water heating system connected to the heat storage tank. The release of heat in the under floor heating system was measured continuously. If necessary, heat could also be supplied electrically in the heat storage tank by a 4.5 kW resistance heater. The ventilation system is also provided by an electrical post heater of 0.9 kW for the supply air. Except from the convective and radiative heat losses from the pellet stove to the indoor environment the supply of heat from all sources in the heating system has been measured.

The EAHE pre-heating of the incoming outdoor air is a 36 m long tube, of which 24 m of diameter 0,2 m is buried 1.5 m deep in the ground outside the house and 12 m of diameter 0.16 m is buried in the ground underneath the house. The heat in the exhaust air is recovered by a heat exchanger to the incoming pre-heated outdoor air. The supply air in the house is distributed through vents in the ceiling into the open space of the living room and into the bedrooms. The exhaust air is taken through open drains in the bathroom, laundry room and drains for the dishwasher in the kitchen. The thermal insulation under the slab on ground, in the external walls and in the ceiling are made of foam glass of thickness 0.306, 0.357 and 0.408 m in the foundation, in the external walls and in the ceiling respectively. Based on the blue prints the building contractor estimated the energy demand for SH and DHW to 11400 kWh/year and the average U-value was given to 0.14 W/m^2 °C. The estimation was based on a fan controlled air flow of 62.3 liters/second, an air leakage of 0.22 [liters/s enclosing area] at 50 Pa, and a temperature efficiency in the exhaust air heat exchanger of 80 %.