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A comparison of the energy consumption in two passive houses, one with a solar heating system and one with an air–water heat pump

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ABSTRACT

Detailed measurements of the auxiliary energy consumption for space heating and domestic hot water preparation in two detached passive houses south of Oslo are reported for the full year 2013. The study compares two equal, new built houses heated with different technologies, one by solar thermal heating and the other with an air-to-water heat pump. The houses are built by central actors from the building industry with high potential of being representative for a sizable, new-built housing stock rather than with focus on system optimisation. The results show that the need for additional energy, corrected for differences in domestic hot water consumption and indoor temperature, is 15–20% higher in the heat pump heated house than in the solar heated house. However the general energy consumption exceeds significantly the dimensioned figures for passive houses in Norway. The measurements demonstrate that solar thermal heating is competitive with heat pump technology even at high latitudes under Norwegian climate even in the case of a non-optimised system. With the available data potential heating system design improvements were pointed out.

1. Introduction

The aim of present work is to explore the performance of two renewable energy technologies for heating residential buildings. Neither the buildings nor the technical installations are highly sophisticated, but are representative for the way the technologies are dimensioned and integrated by the building industry in practice. Heat pumps are quite common in Norway, and have been so for decades due to the fact that 96% of the electricity in Norway is delivered by hydro power [1]. Solar thermal energy applications are, on the other hand, not very common in Norway and part of the study was to investigate if solar energy can compete with heat pump technology at high latitudes.

Statistics published on the energy consumption in Norwegian houses reveal that the energy savings due to various active or passive energy saving technologies are on the average rather moderate [2]. The potential energy savings of heat pumps and solar thermal systems are known, but it is unclear why these potentials are often not revealed by the common practice and the building industry. Hence detailed studies with high time resolution of the energy dynamics in typical mass produced buildings are proposed.

Heat pumps, in particular air source heat pumps for heating buildings have been very popular in the Europe since 2005 [3]. Presently, a group of six countries (France, Sweden, Germany, Italy, Norway and Finland) generate more than 80% of the total renewable energy production from heat pump technology [4]. Considering the pro capita penetration, Norway has the second largest contribution with 0.81 GWh produced per 1000 inhabitants. A survey by Statistics Norway on the *Energy consumption in households* shows that the energy savings in houses after the installation of a heat pump is rather marginal on an annual basis and considerably below 10% [5].

By the end of 2011, the largest Nordic Housing Cooperative OBOS [6] finished Norway's first passive house field at Rudshagen in Oslo [7], consisting of 17 identical detached houses, all heated by air-to-water heat pumps except for one where a combined solar heating system for domestic hot water (DHW) preparation and space heating (solar combisystem) was installed. Two of these houses were made available for a comparative energy monitoring study. The auxiliary energy in both houses is provided by the electric grid. As the present study lacks a large ensemble of equal objects, the unique characteristics is that it includes and compares two equal, new-built houses, with equal inhabitants but heated with two different technologies.

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Fig. 1. Left: site map of Rudshagen passive houses. Right: the two passive houses that are measured in the present study: House B with the heat pump at the r.h.s. and the solar heated House A at the l.h.s. (photo: Tove Lauluten).

It is well known from earlier studies that the energy consumption in homes strongly depends on the inhabitants and their individual user behaviour. The mismatch of the expected and actual performance of low energy houses could be explained by occupant behaviour [8–11] or by poor construction quality in buildings [12]. Concerning the occupant behaviour, a large ensemble is necessary in order to gain statistical significance in a comparison of heating technologies and energy demands in buildings. In a large European project with 14 different housing projects in five European countries (CEPHEUS project) the energy consumption and indoor temperatures were measured in more than 200 passive houses [13]. The statistical spread of the measured results within one project was large but the overall conclusion was that the CEPHEUS project proved the viability of the passive house concept and showed that the space heating demand can be considerably reduced for a relatively small extra cost by keeping a high level of comfort.

However monitoring studies are reported, which show that energy-saving design of low energy houses do not always reveal the expected, reduced energy consumption [8,9].

Energy metering in passive houses with various heating technologies, heat pump and solar thermal energy, have been performed [14–17], however the present study is the first one where solar thermal heating and heat pump technology is directly compared at the same location and in equal detached houses. The disadvantage of comparing only two monitoring cases is partly compensated by precise monitoring of a large number of parameters in real time, all related to the use of heat and the installations related to heat supply. A more comprehensive energy analysis than in [18] is presented. The total energy consumption and the various contributing factors and the monitoring data of the full year from January to December 2013 were available.

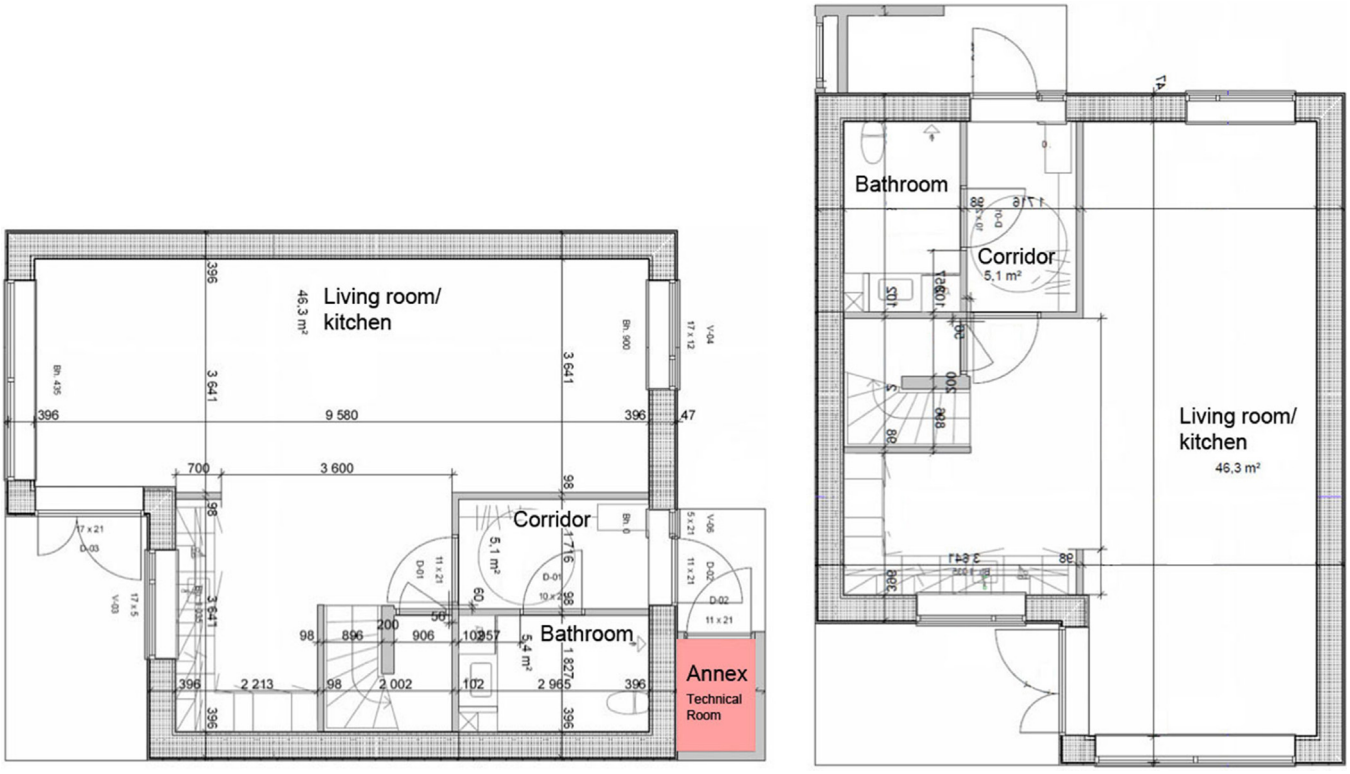

Fig. 2. Floor plan of the ground floor of the solar heated House A (left) and heat pump heated House B (right). The main difference between House A and B is that the technical (boiler) room in House A is placed outside the highly insulated passive house shell. It contains the heat store with pumps and pipes for the heating system.