Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 567–573

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Energy measurements at Skarpnes zero energy homes in Southern Norway: Do the loads match up with the on-site energy production?

Åse Lekang Sørensen[a]*, Anne Gerd Imenes[b,c], Steinar Grynning[a], Tor Helge Dokka[d]

[a]*SINTEF Building and Infrastructure, P.O.Box 124 / Blindern, 0314 Oslo, Norway*
[b]*University of Agder, Campus Kristiansand, Gimlemoen 25, 4630 Kristiansand S, Norway*
[c]*Teknova, Gimlemoen 19, 4630 Kristiansand S, Norway*
[d]*Skanska, Postboks 1175 Sentrum, 0187 Oslo, Norway*

Abstract

Five houses are designed as zero-energy homes in Skarpnes, Norway. The energy goal is to achieve net zero-energy balance on an annual basis. The houses have heat pumps and solar cells (PV). Energy use and delivered energy have been monitored from June 2015. Variations between calculations and measurements are explained by technical and non-technical reasons. For the first year, higher than expected energy loads result in a solar energy cover factor of 65–87% of delivered electricity. The PV generation performs satisfactorily, hence, it may be possible to achieve energy goals during later years provided technical adjustments or behavioral changes.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Zero energy homes; Zero Emission Buildings; Energy measurements; Photovoltaic system, Building energy simulations; Norway

1. Introduction

Smart Village Skarpnes is located close to the city of Arendal in southern Norway (58.43°N, 8.72°E). The village is near its completion and will consist of seventeen single-family houses and three apartment blocks when finished. Five detached houses are designed as zero energy homes. These were finalized in 2014/2015. The five houses are pilot building projects within the Research Centre on Zero Emission Buildings (ZEB). The buildings are designed according

* Corresponding author. Tel.: +47 452 68 682.
E-mail address: ase.sorensen@sintef.no

1876-6102
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.743

to the ZEB-O definition [1], where the carbon emissions due to operational energy use should be zero on an annual basis. All energy items, also plug loads, are taken into account.

As part of the research carried out in ZEB and the project EBLE "Evaluation of Buildings with Low Energy-consumption", the energy performance of the buildings is measured. In the project "Electricity Usage in Smart Village Skarpnes", the solar power production and the electrical consumption is analyzed. This paper presents the method for energy monitoring and one year of measurements from the five homes, from June 2015 onwards. In addition, the distribution of electricity production is compared with the energy consumption, on monthly and hourly basis, and the degree of matching is characterized in terms of load cover factors.

1.1. Building design

Each of the five zero energy homes has a heated floor area of 154 m^2, divided on two floors. There are four bedrooms in each home. The five buildings meet the requirements of the Norwegian passive house standard [2]. The form and architecture is rather conventional for new dwellings in Norway. However, the roof construction is asymmetric to enhance solar energy production from building integrated photovoltaic (BIPV) modules [3]. The solar modules are replacing exterior cladding of the sloped roof, as shown in **Feil! Fant ikke referansekilden.**. The slab on the ground is a concrete slab with EPS insulation and the cellar walls are made of core insulated lightweight aggregate blocks. The roof construction is made of prefabricated trusses, while the external wall has a wood-frame wall construction with additional insulation layers both on the inside and outside. The window sizes and distribution were designed to give adequate daylight conditions in different rooms. The windows facing east, south and west have external solar shading.

Table 1. Building and climate data for each of the five zero energy homes in Smart Village Skarpnes, Norway.

U-values: External walls/roof/floor on ground/windows and doors [3]		0.12 / 0.08 / 0.09 / 0.80 W/m²K
Normalized thermal bridge value		0.03 W/m²K
Air tightness, air changes per hour (at 50 Pa)	Design phase value [3]: 0.6	As built-values: 0.4 - 0.51
Yearly mean ambient temperature		8.0°C

Figure 1. Zero energy homes.

1.2. Energy system design

The need for heating and domestic hot water (DHW) is covered by a ground source heat pump. Each dwelling has a 90 meter deep borehole. The houses have balanced ventilation systems with a rotary wheel heat recovery. In addition, the fresh air is preheated in the winter with the ground source brine loop, which also can be used to cool the air slightly in warm summer periods. The total efficiency of the rotary wheel and the preheating system is estimated to be 86%. The heat distribution system is a waterborne floor heating system. All houses have heating in the bathroom floors and some houses have floor heating also in other rooms. Additionally, there are one to two convectors installed in each house, also heated by the waterborne heat distribution system. DHW is primarily heated by the heat pump, with peak load covered by an electric element. Hot water is also provided to a hot-fill dishwasher and washing machine.

The BIPV system on each house consists of 32 mono-crystalline silicon PV modules [4]. The roof has a pitch angle of 32°, where the PV modules are placed on the southernmost facing roofs, ranging from +48° (South-West) to -51° (South-East) in azimuth angle. The total installed PV capacity per house is 7.36 kW$_P$, connected to a 7 kW three-phase inverter. The system is connected to the electrical grid using a standard 'Prosumer' agreement, where electricity is exported from the solar cells or imported from the grid, as needed.

2. Methods

2.1. Predicted energy need and delivered energy based on as-built input

The predictions for the energy need and delivered energy presented here is a combination of standardized and *as-built* input. The predictions therefore vary from the design phase [3], which were based on standardized values.