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Renovation of Swedish single-family houses to passive house standard – Analyses of energy savings potential

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Abstract

A third of Sweden's two million single-family houses were built in the period 1961-1980, and many of them are in need of renovation. These houses have a high energy use and are in technical terms fairly homogenous. This investigation evaluates the theoretical energy savings potential of renovating houses from this period. Four reference houses were selected and simulated using common renovation measures. The results indicate that most of the existing single-family housing stock will likely not be able to attain the passive house standard after renovation and using today's technology. This is explained by the fact that some house characteristics impose a limiting factor on the energy renovation. Such examples are the shape, foundation and composition of the building envelope. Nevertheless, it is still possible to drastically reduce the final energy use by approximately 65-75 %.

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Keywords: deep renovation, energy retrofit, detailed energy simulations, single-family houses

1. Introduction

Single-family houses built in the period 1961-1980 account for one-third of the energy use in Swedish single-family houses, which in turn use about 40 % of all energy in buildings [1]. These houses were built fairly homogeneous

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in technical terms, with low levels of thermal insulation and heat recovery ventilation (HRV) is rare [2]. Thus there are great potential to improve energy efficiency and indoor environment. A literature review showed few completed deep renovations of single-family houses to passive house level and overall there is little written regarding the subject. Although the initial inventory showed that it is technically possible to renovate to the level of passive house the profitability is questionable. Many of the houses built during this period need to be renovated due to ageing [3]. This provides an opportunity to also incorporate energy efficiency measures.

The overall aim of the research project is to increase the knowledge regarding cost effective deep renovations to passive house level. This will be done through detailed energy simulations, life-cycle cost analysis (LCCA) and life-cycle assessment (LCA) with solutions that preserve the architectural expression of the houses. This investigation is the starting point, focused on estimating the energy savings potential of four reference single-family houses. The simulations were based on the Swedish passive house standard, FEBY 12, (Forum for energy-efficient buildings) [4], as well as a comparison with the current Swedish building regulation, BBR 22 [5].

1.1. Background - Single-family houses built during the 60s and 70s

During the 1960s there was a substantial demand for new housing in Sweden. To overcome this, the "million-program" was initiated with the goal to construct one million dwellings during 1965-1975, including both multi- and single-family houses. To construct this many dwellings in the short timeframe the buildings were built in a standardized way, which makes them suitable candidates for standardized renovations. This project focus on the single-family houses built in the period 1961-1980. From this period there are almost 714.000 single-family houses and they account for much of the energy use in single-family houses, see Table 1. The 1973 international oil crisis increased the costs for space heating, since many houses were heated by oil. The increased energy cost lead to a new focus on reducing the energy use of buildings. As a result the requirements on energy efficiency increased with the building code in 1975, SBN 75 [6], and the result can be seen in the average annual energy demand in Table 1.

Table 1. Number of houses and annual energy demand per heated floor area for space heating and domestic hot water [7, 8].

Years	Units	1961-1970	1971-1980	1961-1980	Total - 2012
Number of houses	thousands (2012)	288	426	714	2014
Average annual energy demand	kWh/m^2/a	106	90	96	106

1.1.1. Constructions used in the 60s and 70s

To compile the commonly used constructions from each of the decades a literature review was performed. It also included finding common shapes and compositions of the building envelope of houses, i.e. form and amount of windows of the building envelope. There was some variation and influences originated both from abroad and from Swedish building regulation. While some constructions were quite standardized, e.g. during 1961-1985 the most common foundation was concrete slab with or without a cellar, which account for over 75 % of all m^2 of foundation in houses from this period [2]. For the concrete slabs the insulation thickness and placement varied between 70-100 mm both above and/or below the slab. For houses with crawl spaces, the joists were filled with insulation [9].

1961-1970 – To accommodate the increased production rate, many houses were built in groups with prefabricated construction. This meant less time at the building site and with the expectation of less building problems. In the beginning of the decade most houses were built as one story houses, alternatively adding a cellar with a recreation room, which in the later parts changed to one-and-a-half or two story houses. Large window sections became common, which increased the window-to-wall ratio, and two types of roof constructions were used, either ridged roof or pent roof. The house shape was either rectangular or L-shaped with function displaced rooms; the rooms were placed based on their use and likely connection, i.e. garage, storage, laundry room and kitchen on one side of the house and living room and bedrooms on the other. The used façade material was either wood panel or bricks or a combination of both [9, 10]. Inside the façade material an asphalt board was placed outside the 100 mm thick stud framework with intermediate mineral wool insulation. On the inside of the wall a diffusion-proof plastic foil was placed to increase the air tightness and lastly a gypsum wallboard. As an alternative construction, light-weight concrete was used with a