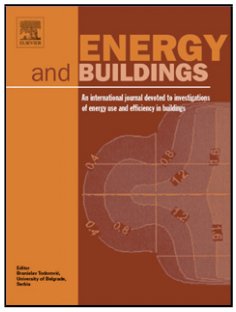

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Cost-effective Passive House renovation packages for Swedish single-family houses from the 1960s and 1970s

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Abstract: This paper evaluates the cost-effectiveness of renovating single-family houses to Passive House level, as compared to maintaining the existing buildings or renovating to building regulation level. The assessment involved life cycle cost analyses, and concerns the Swedish single-family housing stock constructed between 1961 and 1980, which accounts for about a third of Sweden's two million single-family houses. These houses, now in need of major renovation, are represented in this study by two reference buildings. The results show that Passive House renovations can be cost-effective, but this largely depends on the type of heat generation used in the houses. The most cost-effective individual renovation measure was installing an exhaust air heat pump, and the least cost-effective was installing new windows. In houses using direct electric heating, the Passive House renovation package was the most cost-effective alternative.

Abbreviations

BETSI =	Buildings Energy, Technical Status and Indoor environment (national survey)	LCC =	Life cycle cost
BR =	Building regulation	NPV =	Net-present value
DHW =	Domestic hot water	PH =	Passive House
EAHP =	Exhaust air heat pump	PV =	Photovoltaics
EEM =	Energy efficiency measures	RH =	Reference house
FEBY12 =	Forum for Energy Efficient Buildings 12	SDHW =	Solar domestic hot water
GSHP =	Ground source heat pump	SFH =	Single-family house
HRV =	Heat recovery ventilation	SMHI =	Swedish Meteorological and Hydrological Institute
IRR =	Internal rate of return	Sveby =	Standardize and verify energy performance in buildings

Key words: cost-effective, energy efficiency measures, passive house, renovation packages, single-family houses, renewable energy production

1. Introduction

1.1 Background

Single-family houses (SFHs) constructed between 1961 and 1980 account for approximately one-third of the total energy use, 31 TWh per year, for space heating and domestic hot water (DHW) in Swedish SFHs. These houses account for about 40 percent of the total energy use in buildings [1]. There are roughly 715,000 houses from this period [2] and they are largely homogeneous in technical terms, with low levels of thermal insulation, and seldom have ventilation with heat recovery [3]. The average energy use for houses from this period is about 40 percent higher than SFHs constructed between 2011 and 2013 [4].

A survey of the current condition of the Swedish building stock (BETSI) [5] was conducted by the Swedish National Board of Housing, Building and Planning. In this survey, 1800 representative buildings from the entire building stock were inspected to determine the need for renovation [6]. Of these, 821 were SFHs. The survey involved assessments of the technical status, deterioration, lack of maintenance [5], and energy use [3] of the buildings. The need for renovation was found to be extensive. About 70 percent of the evaluated SFHs had some damage – found in all parts of the houses – although most were not categorized as serious. The fact that many of these houses need to be renovated [5] provides an excellent opportunity to incorporate energy efficiency measures (EEMs), to reduce both the operational cost and greenhouse gas emissions related to energy use.

When deciding on the level of energy renovation, there are two main categories of motivators, those that are top-down and based on regulation, and those that are bottom-up and concern the operational cost for the homeowner. The national and international goals for a sustainable future are part of the overall objective to reduce greenhouse gas emissions to mitigate global warming and climate change [6, 7]. The Swedish Government has set a target of a 50 percent reduction in total energy use per heated floor area by 2050, compared to the level in the reference year 1995 [8]. This has led to more stringent requirements on energy efficiency in Swedish building regulations, both for new constructions and when renovating existing buildings [9, 10].