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Utdrag ur: Passive house renovation of Swedish single-family houses from the 1960s and 1970s

Evaluation of cost-effective renovation packages

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LICENTIATE THESIS

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Abstract

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

The BETSI study showed an extensive need for renovation in the SFH building stock. About 70 percent of the evaluated SFHs had some damage – found in all parts of the houses – although most damage was not categorized as severe. The fact that many of these houses need to be renovated provides an excellent opportunity to incorporate energy efficiency measures to reduce both operational cost and greenhouse gas emissions related to energy use.

The aim of this project was to evaluate the possibility for cost-effective renovations of SFHs to Passive House level, while improving the indoor climate. Included in the assessments are thermal comfort and moisture safety, and the alternative of installing local renewable energy production and energy storage. The approach involved theoretically applying the energy efficiency measures to two case study buildings. These reference houses were based on typologies determined from the initial literature review.

The research project began with identifying pilot renovation projects aimed at drastically reducing the energy demand of existing SFHs. Based on the renovation measures used in these projects, possible energy efficiency measures were identified and evaluated to find the

energy savings potential from this type of extensive energy renovation. The results showed great potential, and such renovations could reduce the final energy use by over 65 percent.

This was followed by a sensitivity analysis to determine the impact of different input parameters and building properties of the reference houses used in the energy simulations. These results showed a significant dependence on location of the reference houses if the Passive House requirements were to be fulfilled. The results were also used to limit the number of alternative energy efficiency measures used in the subsequent LCC analysis.

A LCC analysis was carried out to determine cost-effective renovation packages to Passive House level. This built on the previous energy simulations by including the energy costs of adding and evaluating different types of heat generation and distribution systems. This was done to determine the operational costs of the houses and investment cost of implementing the energy efficiency measures. Also included was the alternative of implementing renewable energy production.

The results show that Passive House renovations can be cost-effective, but this is largely dependent on the type of heat generation used in the houses – based both on the difference in operational costs and on the requirements for Passive House. 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.

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Nomenclature

Latin

Atemp	Heated floor area, over 10 °C.	m²
ACH	Air changes per hour	1/h
SFP	Specific Fan Power	kW/(m³/s)
U-value	Thermal transmittance/Heat loss coefficient	W/(m²·K)

Greek

η	Efficiency	-
λ	Thermal conductivity	W/(m·K)
Ψ_k	Linear thermal transmittance of thermal bridge, *k*	W/(m·K)

Abbreviations

AHU	Air handling unit
BBR	Swedish building regulation
BETSI	Buildings Energy, Technical Status and Indoor Environment (national survey)
DHW	Domestic hot water
EEM	Energy efficiency measure
€	Euro
FEBY 12	Forum for Energy Efficient Buildings 12
HRV	Heat recovery ventilation
HVAC	Heating, Ventilation and Air Conditioning
IRR	Internal Rate of Return
LCC	Life cycle cost
MFH	Multi-family houses
NPV	Net present value
PH	Passive House
PV	Photovoltaics
RH	Reference house
SEK	Swedish Crowns
SFH	Single-family house
SMHI	Swedish Meteorological and Hydrological Institute

Sveby	Standardize and verify energy performance in buildings

Appended papers

This thesis is based on the following peer-reviewed journal paper and three peer-reviewed conference papers:

Paper I: *"Renovation of Swedish Single-family Houses to Passive House Standard – Analyses of Energy Savings Potential"* Ekström, T. and Blomsterberg, Å., In the proceedings of the Sustainable Built Environment 16 Conference on Build Green and Renovate Deep, 5-7 October, 2016, Tallinn, Estonia. Energy Procedia, 2016. 96: p. 134-145. *(Ekström & Blomsterberg, 2016b)*

Paper II: "*Renovation of Swedish single-family houses to passive house standard - Sensitivity analysis" Ekström, T., Davidsson, H., Bernardo, R. and Blomsterberg, Å.* In the proceedings of the 3rd Asia Conference of International Building Performance Simulation Association - ASim2016, held on November, 27-29, 2016 in Jeju(Cheju) island, Korea. *(Ekström & Blomsterberg, 2016a)*

Paper III: *"Evaluation of cost-effective renovation packages to Passive House level for Swedish single-family houses from the sixties and seventies" Ekström, T., Bernardo, R. and Blomsterberg, Å.* Submitted to the journal Energy and Buildings, 2017-08-02. (Ekström, Bernardo, & Blomsterberg, 2017)

Paper IV: “R*enovating Swedish single-family houses from the sixties and seventies to net-zero energy buildings” Ekström, T., Bernardo, R., Davidsson, H. and Blomsterberg, Å.* Submitted to Solar World Congress 2017, 29 Oct – 2 Nov, Abu Dhabi, UAE. (Ekström, Bernardo, Davidsson, & Blomsterberg, 2017)

Sammanfattning

Småhus byggda mellan 1961 och 1980 utgör cirka en tredjedel av det totala energibehovet på 31 TWh för uppvärmning och tappvarmvatten i svenska småhus. Dessa använder i sin tur cirka 40 procent av den totala energianvändningen i alla byggnader. Det finns omkring 715 000 småhus från denna period och de är byggda på ett homogent sätt i tekniska termer – med låg isolerings mängd – och de har sällan ventilation med värmeåtervinning. Normalanvändningen av energi i småhus från denna period överstiger dagens småhus - byggda mellan 2011 och 2013 - med cirka 40 procent.

Resultaten från BETSI-utredningen visar på ett omfattande behov av renovering. Omkring 70 procent av de undersökta småhusen hade någon form av skada – vilka hittades i alla delar av byggnaden – även om de flesta inte kategoriserades som allvarliga skador. Faktumet att manga småhus behöver renoveras innebär ett utmärkt tillfälle att samtidigt som de renoveras även inkludera energieffektiva renoveringslösningar för att både reducera driftkostnader men även utsläpp av växthusgaser relaterade till energianvändningen.

Målet med detta forskningsprojekt var att utvärdera möjligheten att genomföra kostnadseffektiva renoveringar av småhus till Passivhus-nivå samtidigt som det leder till andra förbättringar, som ett bättre inomhusklimat. Undersökningen inkluderar även lokal förnyelsebar energiproduktion och energilagring. Även inkluderat i undersökningen är mervärden från att genomföra denna typ av renovering, så som termisk komfort och fuktsäkerhet. Utvärderingarna genomfördes genom att simulera att renoveringslösningar tillämpades på två typhus inkluderade i fallstudien. Typhusen valdes baserat på identifierade typologier från litteraturstudien som genomförts i projektet.

Forskningsprojektet påbörjades genom att söka efter genomförda pilotprojekt som drastiskt minskat energianvändningen i småhus. Baserat på de renoveringslösningar som använts i dessa projekt bestämdes möjliga renoveringslösningar att undersöka för att bestämma den möjliga energibesparingspotentialen från att genomföra Passivhusrenoveringar i småhus. Resultaten visade på en stor besparingspotential på över 65 procent i de utvärderade typhusen.

Som en fortsättning på denna undersökning genomfördes en känslighetsanalys för att avgöra hur stor påverkan vissa parametrar hade på energibesparingspotentialen i den första undersökningen. Resultaten från denna fortsättande studie visade på ett stort beroende mellan energibesparingspotentialen och klimatet samt möjligheten att uppfylla Passivhuskraven. Resultaten användes även för att minska på antalet renoveringslösningar som kom att användas i nästa steg av projektet, utvärderingen av kostnadseffektiva renoveringspaket till Passivhusnivå.

Undersökningen fortsatte genom att bestämma kostnadseffektiva renoveringspaket till Passivhusnivå vilket genomfördes genom en livscykelkostnads-analys som bygger vidare på energisimuleringarna genom att även inkludera energipriser - genom att utvärdera olika typer av värmekällor - och investeringskostnader i analysen. Inkluderat i denna undersökning är även alternativen lokal energiproduktion genom solfångare och solceller samt energilagring i batterier.

Resultatet från livscykel-kostnads analysen visar på att passivhusrenoveringen är kostnadseffektiv, vid användning av vissa typer av värmekällor. Beroende både på skillnaden i driftkostnad och i passivhuskraven. Den mest kostnadseffektiva renoveringsåtgärden var att installera frånluftsvärmepump och den minst kostnadseffektiva åtgärden var att installera passivhus fönster. I hus som använder direktel till värme så är passivhusrenoveringen det mest kostnadseffektiva renoveringspaketet.