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Improvement of Energy Efficiency and Thermal Comfort by Renovation of Social Housing

A Study of Brogården

Eva-Lotta W. Kurkinen, PhD,
SP Technical Research Institute of Sweden;
eva-lotta.kurkinen@sp.se, www.sp.se

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ABSTRACT:
There are many ongoing renovation projects of social housing in Sweden to improve energy efficiency. In these projects, it is not only important to assure an energy efficient renovation but also to guarantee a good indoor environment. To predict the energy use for a renovation object, calculations and energy balances are normally made in accordance with the Swedish BBR (The National Board of Housing, Building and Planning). It is also possible to foresee the indoor environment especially the thermal comfort, by means of calculations. One method is to calculate the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices in accordance with ISO 7730 Ergonomics of the thermal environment. The PMV index gives a mean vote for the assessment of an indoor climate for a representative number of people. The PPD index gives a quantitative prediction oft the percentage dissatisfied in a certain indoor climate.

Brogården in Sweden is a social housing area built in 1970. The area is a pilot project as the buildings will be retrofitted to passive house standard. To ensure the energy efficiency targets and a good indoor environment are met, a quality assurance (QA) system for renovation and maintenance has been applied to the renovation process. The PMV and PPD indices are calculated for the most critical room concerning coldness and for a representative room. The energy target and the range of renovation are compared to other energy efficient renovations in social housing areas in Sweden.

1 Introduction

Energy use in and by a building has the most important environmental impact during the building's life, and is therefore the most important to reduce. New emphasis on energy conservation (such as in the European Energy Performance in Buildings Directive [EPBD, 2002/91/EC]), has added new demands for energy improvements as well. The energy use of a building depends both on the building envelope and on the building services systems which, in their turn, affect the indoor environment. Concentrating excessively on either good indoor environment or energy efficiency might cause mutually negative effects, and it is important to avoid this.

An important part of the energy efficiency improvement potential lies in the existing building stock, especially in the large areas of multifamily housing built before the oil crises in the 1970-ties. If we are to achieve significant reductions of energy use in existing buildings, it is important to perform future large-scale retrofitting of these buildings in a systematic and controlled manner. When retrofitting a building many aspects must be taken into account, such as local resources, costs, building traditions, legislation and financing. These aspects will have an impact on decision-making and on the outcome of the retrofit, which will differ from case to case, and so there are no universal solutions.

2 Energy efficiency

In Sweden there are around 400 000 apartments in social housings built 1960 to 1975 which need some kind of renovation. The annual energy consumption is in general between 150 and 250 kWh/m^2, for heating and electricity. It is of great importance to consider the buildings energy consumption when renovation will be made. It might be possible to reduce the energy consumption by more than 50 % (New multifamily buildings built after 2006 have normally annual energy consumption for heating between 75 and 130 kWh/m^2).

Things to focus on are; insulation thickness at external walls and roofs, thermal bridges, the windows U-value, air tightness, ventilation systems and heating systems.

Calculations are normally made to predict the energy savings for a renovation object,. The different U-values for the envelope and the ventilation- and heating system before and after renovation give a good estimate of the possible energy savings. It is also possible to foresee the thermal comfort by means of calculations.

3 Thermal comfort

The influence of the investigated retrofit measures on the thermal comfort can be evaluated by using the methodology according to ISO 7730:2005 “Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria”.

In the calculation interior and exterior air temperatures, U-values of the building envelope and radiation temperatures will be considered. Factors like clothing, activities of persons and air velocity can be assumed, but different scenarios of user behaviour can be developed and conclusions on the thermal comfort in these cases can be drawn.

The result of the calculation are PMV (predicted mean vote) index and the PPD (predicted percentage of dissatisfied) index. The PMV index gives a mean vote for the assessment of an indoor climate by a representative number of persons. It is based on the principle, that the human thermal balance is achieved, if the heat produced in a human body is equal to the heat which is emitted to its environment. For the assessment of the indoor climate a scale is defined, see the table to left in Figure 1.

+3	Hot
+2	Warm
+1	Quite warm
0	Neutral
-1	Quite cool
-2	Cool
-3	Cold

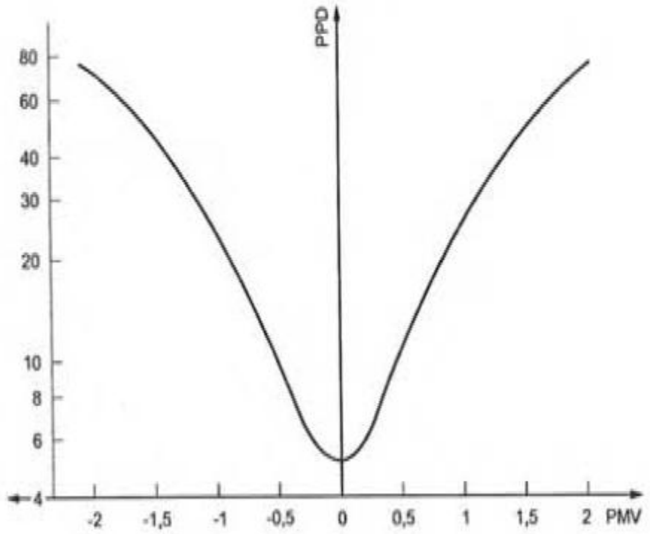

Figure 1. Left, The seven PMV levels of indoor climate assessment. Right, The PPD index as a function of the PMV index.

The PPD index gives a quantitative prediction about the percentage of dissatisfied in a certain indoor climate. “Dissatisfied” people are those, who assess a certain indoor climate with the levels +3 “Hot”, +2 “Warm”, -2 “Cool” or –3 “Cold”.

Based on comparative input data for the calculation according to the ISO 7730, which can be calculated or measured radiation temperatures, U-values or inner surface temperatures of walls, the effect of particular energy efficiency measures can be illustrated by the PMV and PPD indices before and after their implementation.

4 Brogården, Alingsås

The Swedish pilot project Brogården is a social housing area consisting of 300 apartments of the similar type of construction built in 1970, see Figure 2. There are about 1 million similar apartments built in Sweden during the period 1963 to 1973.

Figure 2. Brogården before renovation.

The energy target for Brogården is taken one step further than earlier renovated objects in Sweden. The municipal housing association, Alingsåshem AB is intending to retrofit the buildings to passive house standard. This will be achieved by: supplementary insulation of the building envelope, additional air-tightening the building envelope, changing to super-insulated windows, installing high efficient air-to-air heat recovery.

In the first step eighteen apartments are retrofitted. Experience from the first part will be continuously transferred to the process of retrofitting the remaining 282 apartments. The whole project is expected to be finalized in 2012 whereas the first part will be ready in early 2009.

The traditional heating system consisting of hydronic radiators will be substituted for small hydronic reheaters, one in each apartment. They will only be activated at very low outdoor temperatures. In the summertime tap water will be heated by solar panels. In the wintertime the tap water will be heated by district heating, and so will the reheaters. The goal is to reduce the energy consumption from approximately 216 kWh/m^2 to 91 kWh/m^2 (including household electricity). This means energy consumption well below the values set for new buildings in the Swedish building code. Figure 3 shows the building envelope and installations before and after renovation.

As well as the energy targets, Brogården will also fulfil the requirements of the Swedish quality assurance (QA) system P-marked indoor environment, SPCR 114. To ensure that the most efficient measures are chosen and that a high level of integrated energy and indoor environmental performance is maintained throughout operation of the buildings a special QA system is applied.

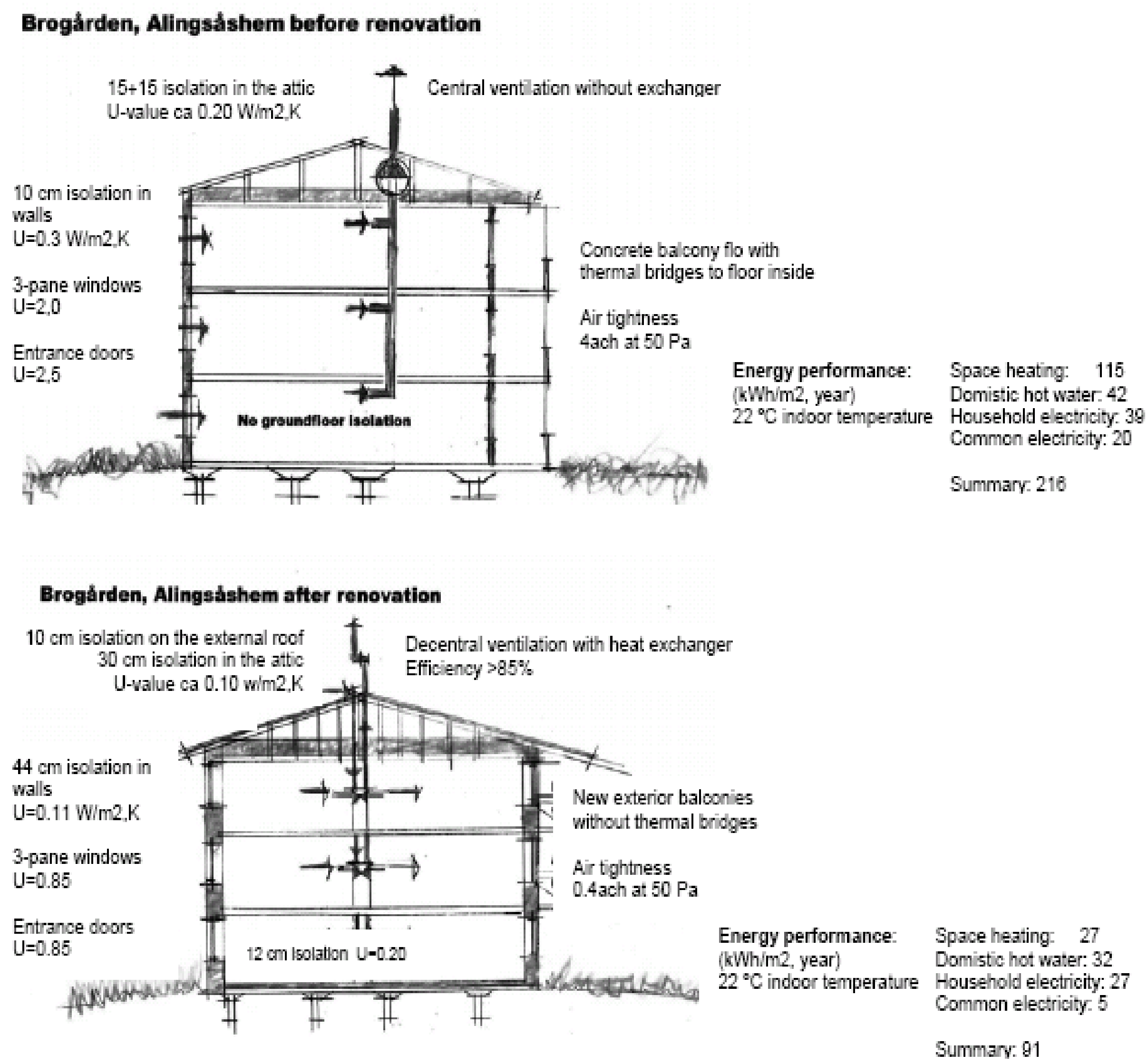

Figure 3. Building envelope and installations before and after renovation. Illustrations made by Hans Eek.

4.1 The QA system and its implementation in the building process

The QA system is developed within the ongoing IEE financed European project, SQUARE (A System for Quality Assurance when Retrofitting existing buildings to Energy efficient buildings). The overall objective of the QA system is to ascertain that all predefined requirements on indoor environment and energy use performance are reached, i.e. that none of them are reached at a high expense of another. Two main parts can be distinguished in the process. The part associated with the management/supervision of the process of retrofitting the building and the part associated with the management of the retrofitted building.

The basic outline of the QA system was introduced in this project in the planning stage. The functional requirements and energy targets were set up. Firstly, thorough inspection was made to localize shortcomings in the building and problems with the indoor environment at an early stage. The investigation showed that the apartments were draughty, there were moisture problems in the slab on ground floor, the façade was in a very bad condition and the balconies acted as cold bridges.

In the tendering procedure, interviews were held with all contractors and sub contractors involved in the building process to inquire them about engagement, values, quality conscious etc. A main contractor and subcontractors were selected and engaged in long term partnering contract with common targets and an open cost accounting. Before starting the renovation, the consortium held an information meeting and education for all parties involved, to give information of the background and development of the project as well as to get a common educational level, foundation of values and common targets. The intention is to get an open climate that will encourage questions, suggest improvements and personal responsibility.

The function requirements will be followed up in the building process. One example is job planning before critical elements such as air-tightness and verification with test pressure loading. When the renovation is finished other functional requirements like thermal comfort, ventilation, light, acoustic environment etc. will be verified with measurements. The energy use will be measured and followed up during operation of the building. The indoor environment will be checked regularly with inquiries to tenants and periodic inspection and measurements.

4.2 Calculation of the PMV and PPD indices before and after renovation in Brogården

The indices are calculated for two rooms. One living room on the ground floor, which is classified to probably be the coldest and a room on the top floor, which is a typical representation of most rooms in Brogården. The living room is 20 m^2 and has two external walls of totally 14.7 m^2. The total window area is 6 m^2. The room on the top floor is 14.8 m^2 and has one external wall of total 8.3 m^2. The total window area is 2.2 m^2. Figure 4 shows where the rooms are located in the considered building.

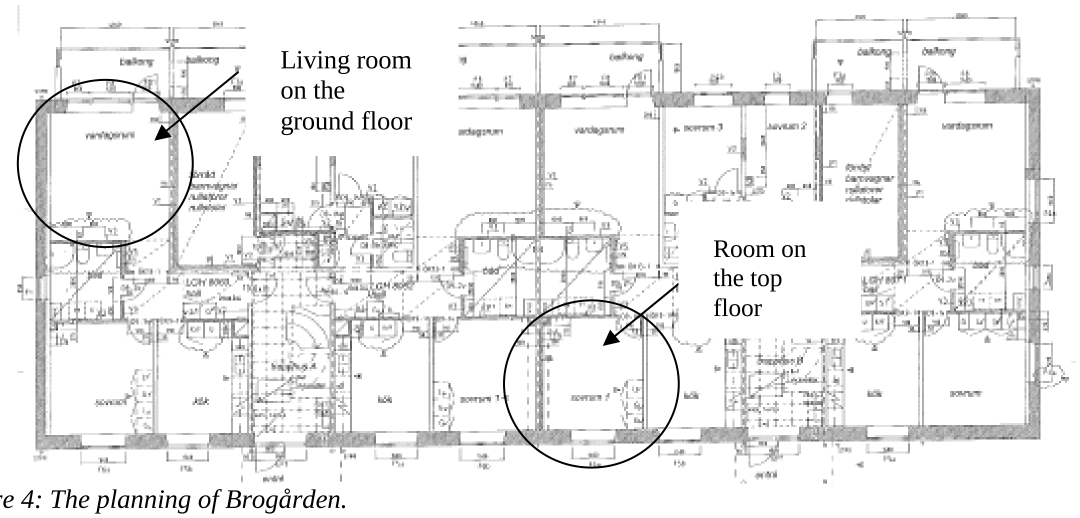

Figure 4: The planning of Brogården.

Table 1 below gives information about the building before and after renovation.

Table 1 U-values before and after renovation in Brogården.

Building component	**U-value, before** $W/(m^2 \cdot K)$	**U-value, after** $W/(m^2 \cdot K)$
Floor	0.35	0.20
Walls	0.30	0.11
Windows	2.0	0.85
Ceiling	~0.20	~0.10
Relative air velocity*	0.2 m/s	0.1 m/s

* The values are assumed.

The indices are calculated for three different outdoor temperatures, -10 ºC, 0 ºC and 10 ºC. The occupants in the room suppose to have long trousers and a shirt or blouse (=0.8 clo). They are sitting or standing (=1.2 met). The standard inside temperature is 20 ºC. The effect of possible solar radiation through the windows is not considerd in these calculations.

The PPD index as a function of the PMV index is shown in Figure 5 and 6. The triangles mark the situation before retrofit and the circles after retrofit. Figure 5 shows the indices for the living room on the ground floor and Figure 6 shows the indices for the room at the top floor.

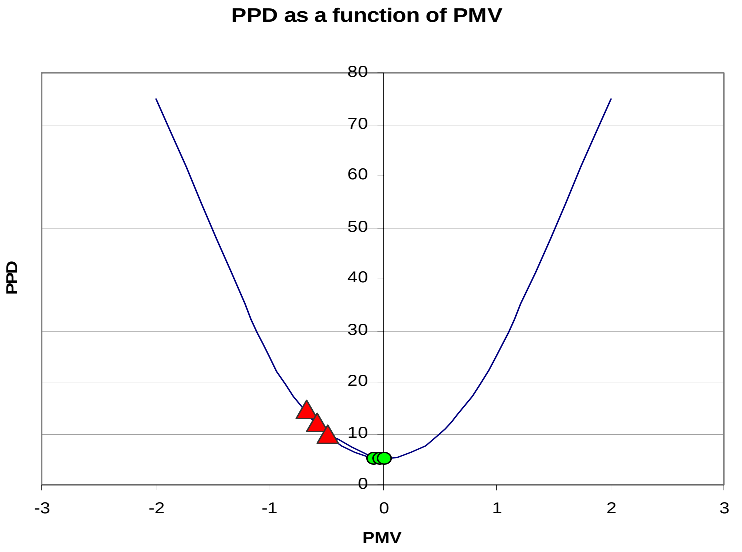

Figure 5: The PPD index as a function of the PMV index for a living room on the ground floor in Brogården. The triangles mark the situation before retrofit and the circles after retrofit. The calculations are maid for the outdoor temperatures -10 ºC, 0 ºC and 10 ºC.

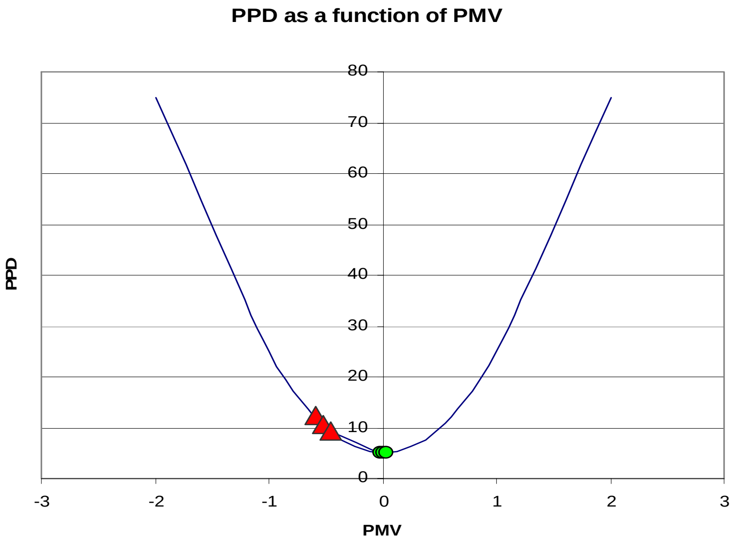

Figure 6: The PPD index as a function of the PMV index for a room at the top floor in Brogården. The triangles mark the situation before retrofit and the circles after retrofit. The calculations are maid for the outdoor temperatures -10 ºC, 0 ºC and 10 ºC.

It can be seen in Figure 5 and 6 that around 10 % of persons experience the indoor temperature as quite cool before the renovation. After the renovation almost all persons will be satisfied with the thermal comfort inside the rooms in question. The calculation of PPD and PMV indices indicate the renovation of Brogården will improve the thermal comfort inside the apartments with around 5 %.

5 Comparison of energy efficiency in renovated social housing in Sweden

In Sweden some areas with social housings have already been renovated energy efficient. Two good examples are Orrholmen in Karlstad and Ringdansen in Norrköping. In Table 2, data for Orrholmen, Ringdansen and Brogården are found. The renovation goal for Brogården is to reach passive house standard therefore more insulation and lower U-value in the windows will be used compared to Orrholmen and Ringdansen. In Brogården will decentral ventilation with heat recovery will be used as well as a higher demand on air tightness compared to the earlier renovated objects.

Table 2 Comparison of energy efficient renovation in three social housing areas in Sweden.

Project name (location)	Orrholmen (Karlstad)	Ringdansen (Norrköping)	Brogården (Alingsås)
Supplementary insulation, facade	70 mm EPS + rendering	50-80 mm EPS+ rendering	New wall 435 mm mineral wool
Supplementary insulation, roof	200 mm	300 mm	380 mm +50 mm
Windows	New, U=1,2	Low energy glass inside original 2 pane	New 3 pane, U=0,85
Ventilation system	No heat recovery	No heat recovery	Decentral ventilation with heat recovery
Heating system	District heating +ground heat pump	District heating +ground heat pump	District heating
Other measures	Façade unit joints and joints around balconies and windows were filled with foam	Air tightening around windows	Required air tightness of 0.4 arch at 50 Pa
Energy use before renovation	225 KW/m^2/year	220 KW/m^2/year	216 KW/m^2/year
Energy use after renovation	150 KW/m^2/year	148 KW/m^2/year	91 KW/m^2/year (estimated)
Built	1966-1967	1968-1972	1970
Renovated	2004-2006	2000-2003	2008-

Orrholmen and Ringdansen have almost the same values on the PMV and PPD indices before and after renovation as Brogården, Figure 5 and 6.

6 Conclusions

In Sweden there are around 400 000 apartments in social housing built 1960 to 1975 which need some kind of renovation. The annual energy consumption is in general between 150 and 250 kWh/m^2, for heating and electricity. It might be possible to reduce the energy consumption by more than 50 % by means of renovation. During a renovation it is not only important to assure energy efficiency but also to guarantee a good thermal comfort inside. The thermal comfort may be foreseen by calculations of the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices in accordance to ISO 7730 Ergonomics of the thermal environment. In the calculation interior and exterior air temperatures, U-values of the building envelope and radiation temperatures considered. Factors like clothing, activities of persons and air velocity is also assumed.

Brogården in Sweden is a social housing area built in 1970. The area is a pilot project as the buildings will be retrofitted to passive house standard. This will be achieved by: supplementary insulation of the building envelope, additional air-tightening the building envelope, changing to super-insulated windows, installing high efficient air-to-air heat recovery. These actions are more extensive than what have been made before in renovating social housing in Sweden. Functional requirements such as thermal comfort in Brogården is analytically determined by calculation of the PMV and PPD indices for two critical rooms, one on the ground floor and one on the top floor. The calculations indicate that the thermal comfort in Brogården will be obtained.

To ensure the energy efficiency targets and a good indoor environment are met, a quality assurance (QA) system for renovation and maintenance has been applied to the renovation process. The QA-system is developed within the framework of the IEE-project SQUARE, a quality assurance system for indoor environment and energy use has been adjusted to suit the retrofitting process of social housing in different European countries.

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