Think different – gain more, spend less
A real life example from a passive house refit

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Abstract: *In Alingsås, Sweden, the municipality´s public housing company Alingsåshem got to think outside the box while planning the retrofit of the residential area of Brogården. This resulted in a successful procured partnership with the contractor Skanska, working together, continuously improving the concept while transforming buildings from the 1970s to highly accessible modern apartments using passive house techniques. The low energy targets were met, yet the original positive character and spirit of the neighbourhood was preserved.*

We would like to share our experiences and inspire others to embark on a large scale energy efficient retrofitting. The example shows how the model using procured partnership and involvement enabled the development and use of innovative techniques. Some typical difficulties and success stories concerning energy retrofitting are presented, showing the path towards increased efficiency and rationalization of the construction process.

Holistic approach, Energy efficiency, Retrofitting, Procured partnership

Introduction

In order to address the energy use, the existing building stock is a key priority. Although an increasing number of high profile low energy buildings and passive houses have been erected in Sweden in recent years, there is still a clear demand for more energy-efficient refurbishments and new-builds. The reason for the slow development is most probably that these kinds of ventures still tend to be pilot-projects and as such they are considerably more expensive, and complex, than traditional projects.

In the Brogården project we have managed to reduce the energy demand for space heating by 75%, while ensuring a financial feasability. A holistic approach and active involvement enabled the development and use of innovative techniques. By this real life example of energy-efficient retrofitting we would like to share our methodology to others that are about to embark a large scale energy efficient retrofitting. Brogården is also one of three show cases in the EU funded BEEM-UP demonstration project to support further energy efficient refits.

Background – The Swedish context

Since the end of WWII, the standard of Swedish dwellings has been continuously improving. An important phase was the politically initiated “Million Homes Program” executed between 1965 and 1974. Large amounts of dwellings with modern standards for bathrooms, kitchens

and HVAC systems were built in ten years, thus enabling better living standards for all members of society. The program resulted in 1,000,000 modern dwellings being built for a population of 7.5 million. As by now many of these buildings have reached a point where they are in immediate need of repair this is the time to address both the defects and to enhance the performance of the buildings. In addition to this, the large complexes with repetitive architecture are not currently considered "attractive" by the Swedish population.

The Million Homes were built in an industrial and repetitive manner. As we will show here, the key to renovating them will be to replicate that: to do it industrially and repetitively.

Public housing in Sweden

In contrast to other countries in Europe, Swedish housing companies provide *public housing*, not *social housing*. A large portion of the population, from all social strata, lives in dwellings provided by the municipalities' housing companies. The public purpose of those companies poses demands and ethical, environmental and social responsibilities, often to contribute to a sustainable development and efforts to meet the climate challenge.

A substantial part of the houses built during the Million Homes Program is currently owned by public housing companies. These buildings are parts of a complex problem: beside the need for renovation, increased energy efficiency and an update to meet modern demands on comfort. Demographically, many tenants are economically vulnerable. Housing companies are thus faced with a situation where a launch of major renovations works is required while the rents cannot be increased to cover the costs. New strategies are therefore urgently needed.

Energy and building standards

The Swedish building code during the Million Homes Program-era, BABS 67, states an energy standard equivalent with U-values for floor, wall, roof of 0.40 W/m²/K and windows 2.7 W/m²/K (excl thermal bridges). For a typical apartment in Brogården, the ventilation rate should be approximately 0.5 l/s/m² floor area.

The current building code, BBR20, sets the building standard for an energy demand of 90-130 kWh/m²/a heated floor area for non-electrically heated dwellings and an average heat transmission coefficient of the building envelope (incl thermal bridges) of 0.40 W/m²/K for new buildings. The minimum air exchange rate in occupied dwellings is 0.35 l/s/m² floor area. Although the indoor temperature in dwellings is recommended to +20°C, the real estimated mean temperature is about +22°C [1].

Brogården

The residential area Brogården was built in1971-1973. It comprises 16 houses (3-4 stories high) with a total of 299 flats – all with their own indented balcony or patio. As a typical example of the Million Homes Program - there are thousands of houses in Sweden built with the very same blueprint - Brogården is listed as an area of cultural interest.

The houses in Brogården had poor indoor climate and great energy demand due to major thermal bridges, poor air tightness and insulation combined with insufficient indoor air

quality. Surfaces were worn down, the flats had poor accessibility and the size of flats did not meet modern demands.

Brogården – the refurbishment

All measures needed in Brogården were planned to be coordinated and done in harmony with each other. The houses were stripped down to the concrete skeleton, and then rebuilt using passive house standards. The entire area also got high accessibility both indoors and outdoors. The refurbishment started in 2007 and finishes in September 2014. Work has been done methodically from one end of the area to the other, starting with a pilot house. Evaluations have been made after each finished house.

Figure 1: Brogården façades, balconies and entrances before and after retrofit. Photo: AB Alingsåshem

The tenants have been evacuated during the refurbishment. As houses are finished, tenants have moved back – meaning that evacuated houses, buildings with ongoing construction works and houses with tenants have stood alongside each other. For 299 households this refurbishment has made a notable impact on their daily lives for several years. Still, surveys show that they are happier with their homes now than before the works began.

Brogården – the energy savings

Through the implementation of passive house technology, focusing on high energy performance at good indoor climate conditions, the energy demand of the Brogården area has been significantly reduced. The technology focuses on a high thermal insulation rate and minimisation of thermal bridges, high air tightness in the building envelope and mechanical ventilation with efficient heat recovery (HRV).

An extensive monitoring programme within BEEM-UP in one of the buildings enabled further trimming of the energy performance through the HVAC systems, making full use of the heat recovery. Preliminary results for the first year, partly made before the HVAC adjustments, show that the energy demand for space heating has been reduced by 75%, see Table 1.

Before the refurbishment heating, hot water and household electricity were included in the rent. This most probably led to a negligent attitude towards energy savings. After

refurbishment, heating is largely superfluous and hot water and household electricity are charged individually based on consumption. Economically this has lead to noticeable savings for the housing company and a considerable decrease in the tenants' consumption: Alingsåshem has noted a 20% decrease since the introduction of individual billing.

*Table 1: Preliminary results of energy use before and after retrofit of building H in Brogården [2]. Before retrofit, common and household electricity were not measured separately, thus the separation is an assumption. *Heating degree day adjusted values. ** Area = A_{temp}, Σ interior area of space heated to >10°C.*

House H (kWh/m², year **)	Baseline period 2007 -2008	Reporting period 2013
Heating*	142	35
Domestic hot water	27	22
Domestic electricity	30	31
Common electricity	18	9
TOTAL	**217**	**97**
Mean indoor temperature	Not known	+22 °C

A holistic perspective – the key to success

Through the retrofit, the Brogården buildings have been granted a new, sustainable life. The process itself created valuable experiences and increased knowledge for all members of the team, from skilled workers to designers and decision makers. What makes this project different from many other retrofits, and what makes it a success, is the holistic approach. To us 'holistic' means a mindset where you take care to see the project and related aspects as a united whole. It has enabled us to think of the ecological, social and economical factors and their interdependence all at once. Through this approach we have gained added values to more aspects of our work, and this in a more efficient and cost effective way than achievable through traditional methods.

Take for example the decision to keep the the buildings' concrete structures, instead of tearing them down and build new ones:

- This had ecological benefits, since transportation, new outtakes of mineral resources and disposal of old concrete in landfills was not needed.
- This had economical benefits, since we did not have to dismantle the old structures, decontaminate the grounds and buy and erect new concrete frames.
- This had social benefits, since the listed area kept its layout and the residents had the comfort of knowing that well-loved homes would still be there for years to come.

What we have learned is that aspects of a renovation on this scale are not just lists of separate cases, but circles that overlap. We will highlight this through the key factors "long term perspective", "dialogue and involvement" and "challenges and lessons learnt".

The long term perspective

Brogården is the home of many people, whom must be treated with respect and provided a sustainable living environment. The buildings and the neighbourhood are our long term commitment. The buildings in Brogården are planned to serve for another 50 years, at least, after retrofit. Hence, conventional financial models cannot be applied as they do not comprise

the whole life span of the buildings and tend to narrow the economy to the conventional running and renting of apartments.

Through a retrofitting with a long term perspective, the society benefits from a neighbourhood development that includes accessibility, home care service, shared facilities etc. The benefits might not always be easy to quantify, but even when conservative calculations are used the advantages are clear. By using the real time scale, solutions with low life cycle costs can be found even though they are more expensive initially.

The watchwords of the development have been to keep the quality and the soul of the neighbourhood while addressing technical defects. Several different scenarios were studied over time before deciding on a strategy, e.g. *As is, Replacement* and *Retrofitting to passive house standard*s. The *As is* alternative actually comprises quite a lot of maintenance costs in order to maintain an acceptable living environment, making Brogården a losing business in 15 years time. Looking at the alternatives it was given that the passive house retrofitting scenario will be the most profitable in approximately 10 years [3].

A large part of this can be attributed to the fact that future financial risks are reduced, as costs for operation and maintenance will be significantly lower after retrofitting. There is also a transaction of future behaviour-related risks of energy costs from the building owner to the tenant. The improvement of quality of the buildings and of the neighbourhood will also minimize future financial risks such as vacancies.

Dialogue and involvement
Procured partnership has been a key to success at Brogården. Thanks to this cooperation model everyone involved have been important cogs in the development process: designers, contractors, property managers and residents.

The partnership is a structured and modern form of collaboration where partners form the project together. The expected benefits are production and cost efficiency and continuous improvement of products and service. The partnership is characterized by trust, transparency, shared goals and dedicated partners. In a procured partnership all skills are seen as valuable. Focus moves from contract management to common solutions. A common and open budget, and in Brogården's case even open accounting, is a precondition for a procured partnership. The profit of the contractor is a fixed amount, and every added costs or savings are split equally between building owner and contractor, thus also sharing the incentive.

Each stage of the project has started with an experience recuperation meeting involving every team member on the project. Continuous feedback-loops and evaluations from everyone involved have ensured working conditions and technical solutions to evolve during the project. An example is the evolution of the exterior passive house wall, which has been improved several times in terms of cost and time efficiency, ergonomics, logistics and technical performance. Many of these changes have been initiated by the skilled workers and carried out by the team. The urge for the carpenters to decrease heavy elements of work that

cause stress injuries to elbows and arms resulted in not just 8000 screws less per building but also a quicker and therefore less expensive assembling process. As the structural engineer in cooperation with the framework steel supplier found new ways to connect the frame, the thermal performance of the wall was likewise improved.

Thanks to constant monitoring of the buildings' performances we know for a fact that the solutions chosen are as effective as intended – both regarding indoor climate and reduction in energy demand. The monitoring has also helped us to spot weak points in the construction and ventilation system and amend them before they become a problem.

The project involved a great number of tenants for a prolonged period of time. In order to create security, dismiss rumours and get feedback a continuous dialogue was established with the tenants. It is also much easier to create an understanding for changes made if the recipient has been involved in the early stages of the process. In addition to one-to-one meetings, all tenants have been invited to frequent open houses in a showroom apartment; we have published a newsletter and been available for all sorts of questions. All these actions have been made in collaboration between the housing owner Alingsåshem, the contractor Skanska and the Swedish Union of Tenants.

Through this dialogue we became aware of small but important things, for example that the tenants appreciated their yards but wanted more benches and tables – something that we could easily provide and thus getting a more satisfied costumer.

Experience feedback and lessons learnt
The large scale repetition in the design of the Brogården area has enhanced the possibilities of continuous evaluation and improvement. The high involvement and shared objectives have set every project member on the track to evaluate, learn and improve along the way. With every new building a new iteration has been made, enabling the project as a whole to further improvements of the organisation as well as of technical measures. Hereby, the industrial and repetitive design of the Million homes programme has supported a rational method of work, where the process can be refined along the way while making use of the experiences from each step to the next, building knowledge continuously.

Eg, the evolution of the wall system did not stop with the satisfying result from the first dialogue. Within the BEEM-UP project in 2011, an interdisciplinary team was formed to further develop the wall system towards prefabrication, keeping the same technical performance. Through experience feedback, several mock-ups and tests, a prefabricated wall system has been developed for the three last buildings of the project, as a final answer to the thesis to retrofit these buildings in the same industrial way as they once were built.

Incorporation of old balconies in new dwellings A turning point of the design process was the decision to change the indented balconies to exterior ones, incorporating old balcony area in the apartment. It was a challenge to keep the buildings' expression without adding any extra load to the slimmed concrete frames, still supporting an efficient construction process on site.

The result added extra value not just in terms of energy performance, where a major thermal bridge was cut and passive house performance made possible, but also to the tenants who were given a larger balcony. The building owner gains about 8m² of rentable space per flat, used to enlarge the bathrooms, thus meeting the demands of accessibility and standards of the 21st century.

Accessibility has been a core issue of the Brogården retrofit. With 60% fully accessible flats, social and economic sustainability is granted when tenants can stay in their home through all stages of their lives, significantly reducing public costs for care. Simple solutions can integrate accessibility for all tenants in normal flats. The original inset entrances have been opened and lit up, enhancing guidance for those with poor eyesight while increasing the sense of security for everyone. A lower position of entryphones, hooks and installations enable usage not only from a wheel chair, but also for children. The removal of excessive steps, introduction of seats and extension of handrails improve accessibility for everyone.

The elevator challenge In order to grant access to flats on all floors, highly energy efficient elevators have been introduced in Brogården. The elevators themselves show a great performance thanks to low energy machinery, LED lighting and stand by mode. The key point has been to effectively introduce the elevators in the existing buildings. Space for shafts was found in the layout, but since the listing of the area did not comply with exterior machine rooms on the roof, elevator pits were used initially. However, depending on the building's foundation the pit could not always be made as deep as desired, resulting in high costs for elevator machinery and/or concrete works. Thus, the permission to extend the shaft through the exterior roofs for the last buildings was the final key to the elevator challenge, solving one of very few issues that were not solved through project dialogue, long term perspective, experience feedback and continuous improvement.

Conclusions

The challenges posed to us at Brogården are not unique – nor are the houses. Building owners both in Sweden and in Europe at large are facing the same issuses. What is unique is our way to meet those challenges: we decided to handle the area as a unit, not as separate parts, and we decided to do it in collaboration with different kinds of competences. That holistic approach has meant higher costs initially but will pay back in the long run.

Even though Brogården is unique now, we hope that this approach has inspired others and paved the way for followers. Perhaps some day “thinking outside the box” will be the standard approach in energy-efficient retrofitting.

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