Experiences from New Swedish Passive House Projects

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ABSTRACT: In a Swedish research project carried out at Lund University, new Passive house projects are studied to see what knowledge and components that are necessary to get a more wide spread deployment of Passive houses in a cold climate. The Passive houses are closely followed; from the clients decision on building a Passive house, through the planning process, the building process, measurements of actual energy use after the tenants move in and the tenants' opinions on living in a Passive house. The results show a low need of energy for heating together with high indoor comfort. One investigated Passive house consumed 44 kWh/m^2 per annum of district heating for heating and domestic hot water: a 72% reduction comparison to Swedish averages 160 kWh/m^2 per annum for heating and domestic hot water in multifamily houses. Knowledge among all building team participants about Passive houses is necessary to get a well functioning dwelling.
Keywords: Passive houses, renovation, thermal solar energy, comfort

INTRODUCTION

As one step to decrease the carbon dioxide emissions and put a brake on global warming, more energy efficient buildings must be produced and energy efficient improvements must also be made on the existing building stock. Passive houses are one approach that shows great promise for reducing energy use in housing [1,2,3]. The first Passive house was built in Germany 1991 and very well evaluated. Since the results showed both that the tenants were satisfied and that the energy use for heating was very low, the building of Passive houses continued. Passive houses are now very common in especially Germany, Austria and Switzerland.

The use of Passive houses thus have potential to respond to political decisions such as those currently made in Sweden to improve the cost effectiveness of energy while ensuring low negative effect on health, the environment and the climate. Passive houses provide a means to contribute to the country's plan to decrease the energy use in buildings by 20% per heated unit area before 2020 compared to the energy use in 1995 [4]. It is thus important to investigate how to get a more wide-spread deployment of Passive houses.

SWEDISH PASSIVE HOUSE PROJECTS

The first Swedish Passive house project in was built in Lindås in 2001, ten years after the first Passive house was built in Germany. The Lindås project contains of 20 terrace houses and was built according to the German Passive house standard with a maximum use of space heating of 15 kWh/m^2, year. The project was closely examined and showed good results both in satisfied tenants and high indoor comfort together with low energy consumption [5].

Even though it was proved that Passive houses can be built in a cold climate such as Sweden, not many Passive house projects followed in Sweden after the Lindås project. This lack of new projects laid the foundation to this new research project carried out at the Division of Energy and Building Design at Lund University. Here four new Passive house projects are studied; two apartment buildings, one family house and a renovation project [6]. The research project started in 2005 and will be finished in 2010. In Lindås the finished buildings were studied, in this new study the whole building process is of major interest. It is important to not only look if the building is working and the tenants satisfied. Also how the building is actually built must be studied, to be able to duplicate the projects or detect mistakes that should not be repeated.

The main purpose of this research is to determine what knowledge, components and systems that are needed to achieve more Passive house buildings in a cold climate. By practically participating in the planning group of these four demonstration projects, knowledge is gained about the total building process. General advice and help has been given to architects, consultants and to the clients. Within this research, only residential buildings are studied. The Passive house demonstration building projects studied are 40 rental apartments in Värnamo, 12 rental apartments in Frillesås, a one-family house in Lidköping and renovation of 18 rental apartments in Alingsås.

APARTMENT BUILDINGS IN VÄRNAMO

In Värnamo (latitude 57°12'12 N), in the south part of Sweden, the demonstration Passive house project was finished in June 2006 and the tenants moved in, see figure 1.

Figure 1: Apartment buildings in Värnamo

The unit consists of rental apartments owned by the public housing company in Värnamo; Finnvedsbo-städer. The 40 apartments are distributed in 5 buil-dings and have 2, 3, 4 or 5 rooms. The buildings have a load bearing structure of concrete, cast on site. The slab on the ground is insulated with 300 mm of expanded polystyrene insulation (eps). It also has a double L-insulation around all edges to get a high indoor comfort with no risk of cold floors or cold inner walls, see figure 2.

Figure 2: Double L-insulation in ground construction, Värnamo

The well insulated outer wooden walls and roof are also made on site. In the outer walls there is an installation layer of 70 mm between the plastic foil and the inner gypsum boards (see figure 3).

Figure 3: Installation layer in outer wall, Värnamo

The installation layer saves the plastic foil from holes made by electrical equipment, water and heating pipes and also from nails put up by the tenants and gives a long lasting, air-tight construction. The entrance door is custom made for this project, to be able to get a door with the required U-value. The U-values are consist-ently low, as can be seen in table 1.

Table 1: U-values in constructions used in Värnamo

Construction:	U-values (W/m^2K)
Floor facing ground	0.09
Outer wall	0.10
Roof	0.07
Outer door	0.06
Windows	0.94

To avoid too high indoor temperatures, solar shadings are well thought through in the project. The ratio of window area (incl. window frame)/floor area is 16%.

The apartments are heated by air. Each apartment has an air-to-air heat exchanger with an efficiency of 85%. On cold days, when additional heat is needed, this is provided by an electrical heating battery, placed in the ventilation unit. All five buildings have solar panels on the roof, producing domestic hot water. Electrical boilers produce domestic hot water in the winter. Both the domestic hot water and the heating batteries in the ventilation units get electricity from a wind power station. No district heating is used in this project.

Actual energy use has been measured since the day the tenants moved in. Heating, domestic hot water and house hold electricity is measured together with indoor temperature. The tenants pay for their own consump-tion and can easily read all measured figures on the internet, the measurements are updated daily. The measurement between 1st February 2007 – 1st of February 2008 show a mean value of the amount of bought energy of 65 kWh/m^2, year (energy for heating, domestic hot water and house hold electricity). The mean value of the indoor temperature in all apartments is approximately 22°C. The highest measured indoor temperature is in one apartment 25.6°C and the coldest is measured in an apartment where the heating battery (deliberately) is not used; 17.4°C. The maximum outdoor temperature during this period was measured to 32.6°C and the minimum outdoor temperature was measured to -14.7°C.

A questionnaire has been sent out to the tenants and shows a high satisfaction of the living quality in the Passive houses in Värnamo. The client Finnveds-bostäder is also very satisfied and has continued building Passive house apartments.

APARTMENT BUILDINGS IN FRILLESÅS

In December 2006, 12 apartments built as Passive houses were finished in Frillesås (57°19'0"N) on the Swedish west coast, see figure 4. The client was the public housing company Eksta Bostads AB, who already in the 60s started to build solar panels on their apartment buildings for domestic hot water production. The three buildings in Frillesås contain two, three and four room apartments.

Figure 4: Apartment buildings in Frillesås

The concrete load bearing construction is partly prefabricated and completed on site. The outer wooden walls are also partly prefabricated – the inner wooden core were produced in a factory and completed on site with eps insulation on both sides. On the inside surface of the outer wall construction, plastic foil is mounted, followed by an installation layer of 35 mm. The U-values of the major constructions is showed in table 2.

Table 2: U-values in constructions used in Frillesås

Construction:	U-values (W/m^2K)
Floor facing ground	0.11
Outer wall	0.11
Roof	0.08
Outer door	1.0
Windows	0.7

A glazed vestibule supports the somewhat high U-value of the outer door and guarantees a high indoor comfort around the entrance, see figure 5. The ratio of window area (incl. window frame)/floor area is 17%. A major target for the client is to decrease the use of electricity in their apartments. A solar system supplies the apartments with domestic hot water in the sunny season and is complemented with district heating.

Figure 5: Glazed entrance vestibules, Frillesås

The apartments are heated by air. Additional heat is supplied by a water borne battery, heated by district heating or solar panels. The actual energy is continuously measured together with indoor temperatures. Measurements between 1st February 2007 and 1st February 2008 shows a mean value of bought energy of 83 kWh/m^2, year. Within this, 44 kWh/m^2,year is used for heating and domestic hot water and is supplied by district heating. The rest, 39 kWh/m^2,year, is used as household electricity. The mean value of the indoor temperature in all apartments is 22.4°C and the highest measured temperature is 28.2°C, the lowest 17°C. The maximum outdoor temperature during this period was measured to 31°C and the minimum outdoor temperature was measured to -9.9°C.

ONE FAMILY HOUSE – VILLA MALMBORG

In Lidköping close to lake Vänern (58°27'55"N), the first Swedish one family Passive house was finished in April 2007. It is in two storeys and the living area is 171 m^2, see figure 6.

Figure 6: Villa Malmborg, Lidköping

The house is a prefabricated wooden construction, mounted on a concrete slab on the ground. To be able to prefabricate the outer wall and also get the required U-value, the wall was made in three layers, see figure 7, mounted at site. The U-values of the constructions are presented in table 3.

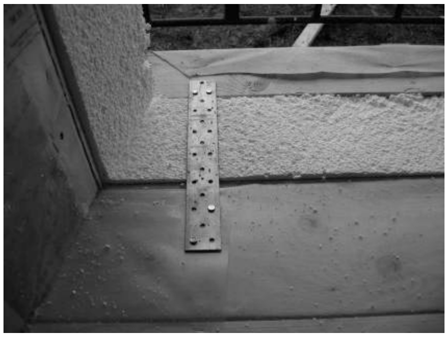

Figure 7: Three layer construction of outer wall, Lidköping

Table 3: U-values in constructions used in Lidköping

Construction:	U-values (W/m^2K)
Floor facing ground	0.10
Outer wall	0.09
Roof	0.07
Outer door	1.4
Windows	0.85

The house is placed on the fringes of an area with new one family houses. The eastern façade is facing an open field of corn, giving a marvellous view but no solar shading. There is no additional solar shadings on the eastern façade, see figure 8, giving a high indoor temperature on sunny summer days. The original eastern window on the upper floor was not operable. This has now been changed, giving the family airing possibilities also on the upper floor and with that a better indoor comfort. The ratio of window area (incl. window frame)/floor area is 15%.

Figure 8: Eastern façade with no solar shadings, Lidköping

The house is heated by air with an air-to-air heat exchanger with an efficiency of 85%. In cold days additional heat is supplied from district heating. Domestic hot water is also supplied by district heating. In the original concept, solar panels were supposed to be mounted on the solar shadings on the south façade. Unfortunately, the district heating company said no to this solution and to be able to buy district heating, no solar panels were installed. The actual energy use is now measured, together with indoor temperatures. Early results show that the amount of bought energy for space heating is 20.8 kWh/m^2 during the first year. The maximum outdoor temperature during this period was measured to 33.7°C and the minimum outdoor temperature was measured to -11.5°C.

APARTMENT BUILDINGS – RENOVATION

The Brogården area in Alingsås (57°55'48"N) was built in 1970 (figure 9) and now it is time for a major renovation. The tenants complain about draught and uneven indoor temperatures and the client have high costs for heating. To ensure both a high indoor comfort and low need of energy for heating, the Brogården area will be renovated to Passive houses.

Figure 9: The Brogården area, Alingsås

The brick facades are worn out and need to be changed, see figure 10. This gives a great opportunity for adding insulation in the outer walls before the new façade material is mounted. It also gives an opportunity to eliminate a large thermal bridge in the balcony construction. In the original construction, the balconies were a part of the load bearing concrete building construction, see figure 11.

Figure 10: Worn out brick façade, Alingsås

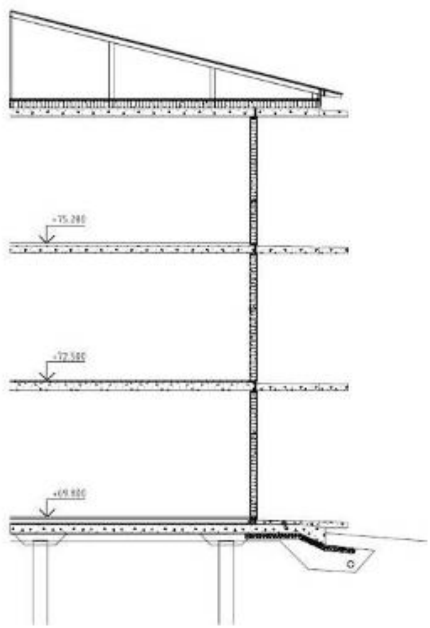

Figure 11: Original balcony construction, Alingsås

The throughout concrete caused a large thermal bridge with low floor temperatures in the room inside of the balcony. To avoid this thermal bridge, the balconies are moved. Since the long side walls needed to be new built, they could be moved to a new position. The outer part of the balcony is removed, giving an even line on the long sides where the new long side walls are placed. The balconies are standing on plinths, mounted on the outside of the façade.

The outer doors and windows are changed to new with low U-values. All U-values are presented in table 4. Measurement of the air tightness before and after renovation shows of an improvement from 2 l/s,m^2 be-fore renovation to 0.2 l/s,m^2 after renovation (surface related to leaking area) at an air pressure of 50 Pa. Measurement of actual energy use and indoor temp-eratures will start when the tenants move in at February 1st 2009.

Table 4: U-values in constructions used in Alingsås

Construction:	U-values (W/m^{2}K)
Floor facing ground	0.20
Outer wall	0.11
Roof	0.3
Outer door	0.75
Windows	0.85

PROJECT PLANNING

It has been shown that to be able to build a well functioning Passive house, all participants in the planning group need to work together. The traditional way of planning using a relay race with the architect starting, handing over to the constructor and finalizing with the HVAC consultant, who gets the drawings with the already fixed design and construction trying to ensure that the building will have a suitable indoor climate and that the energy requirements will be fulfilled, is not working.

Everyone needs to work together in order to achieve the set up requirements, for instant regarding indoor climate and energy needed for heating. This way of working also avoids information to disappear between the different consultants when the baton is handed over. The HVAC-consultant needs to discuss early with the architect the placement of the ventilation unit, to ensure a low noise level from the fans. They also need to discuss the placement of ventilation ducts, getting the placement right for an adequate ceiling height. It is important for the architect to choose surface materials that will guarantee a comfortable indoor climate for the client, not having a traditional heating system. Since the Passive house walls can be very thick, tilted window angel bays are a good way to open up the windows, giving a good indoor natural lightening.

LEADERSHIP

Experiences from this research show that everyone on site needs to be educated about Passive houses to get a good final result. The one demonstration project that ran most smoothly had a project leader that had done his homework well regarding Passive houses, being able to answer questions straight away, keeping the project going, both in the planning process and during construction. This project leader also knew what final results that are desired from the client and firmly steered the project in this right direction. All contractors were then clear about the set up require-ments and fewer unexpected incidents occurred in the project.

FUTURE WORK

Future work within this research project will include interviews with the tenants, following up the measured results of energy consumption and indoor temperatures, to make sure they are satisfied with living in a Passive house. The building process of the renovation project will be closely followed and when finished, measurement of energy consumption, indoor temperatures and moisture content in the constructions will be measured.

CONCLUSION

This research project shows that it is possible to build Passive houses in a cold climate with a very good result. The measured bought energy for heating and domestic hot water in one project of 44 kWh/m^2, year is a 72%

reduction in comparison to the average energy use in Swedish multifamily houses of 160 kWh/m^2, year for heating and domestic hot water [7]. The tenants are satisfied with their indoor climate and the energy use for heating is low. To get these good results the building process needs both project leaders and carpenters that are familiar with the Passive house concept. There is no special architecture needed to build a Passive house, except for using moderate window area. Regular building material is used in all these demonstration projects, but the construction must be well thought through considering both over- and subnormal indoor temperatures, to get a good indoor climate.

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