

8 Summary

To achieve a Swedish energy supply that is effective and durable over time, political decisions are made to get the energy supply cost effective with low negative effect on health, the environment and the climate. The decisions should also make it easy to change already existing energy supply devices towards a more sustainable ecologically society. Renewable heat sources and energy efficient solutions are areas prioritised.

The sector of dwellings and service organizations uses 36% of the total energy in Sweden. In June 2006, it was decided by the Swedish parliament that the energy use in residential buildings and premises should decrease by 20% per heated unit area before 2020. At the year 2050 the energy use should be halved. Before 2020 the dependency of fossil fuels for heating buildings must be broken off. To reach this goal, more energy efficient buildings must be produced as well as energy efficient improvements must be performed on the existing building stock.

The first passive house in Sweden was built 2001, ten years after the first passive house was built in Germany. The passive house concept is not an energy performance standard, but a concept to achieve high indoor thermal comfort conditions at low building costs. The basic idea of a passive house is a well insulated, air-tight construction with mechanical ventilation. Building components which are necessary in any case; the building envelope, the windows and the ventilation system, are optimized to make the need of energy for space heating as low as possible. Thermal bridges must be avoided, as must air-leaking through the building envelope. To achieve a comfortable indoor climate in such an air-tight building it is necessary to use mechanical ventilation. If the construction of the building ensures that the peak load for space heating is less than 10-16 W/m², the ventilation system can also be used for space heating. In Swedish passive houses typical air flow rates are about 0.5 ach. When using a ventilation heat exchanger, the temperature of the supply air delivered to the living area is preheated by the exhaust air, which helps to keep a comfortable indoor temperature. The heat exchangers should have an efficiency of at least 80% to minimize the ventilation losses. The maximum temperature of the supply air should be about 52°C. The unit also needs to be very quiet and it should be easy to change filters. The unit must be easy to clean and the energy use for the fans in the unit must be low. Furthermore, the ventilation system has to be equipped with a bypass of the heat exchanger to keep the indoor temperature low in the summer.

A standard has been set up to be used on a voluntary basis when building a passive house in Sweden, with for instant a few requirements on the building envelope up to make sure that the building will function as a passive house. In excess of this standard the Swedish regulations BBR should be followed (BBR, 2006). Standard solutions for the integration of wood stoves into passive houses do not yet exist and needs to be carefully planned in each project.

The method used in this research is to practically participate in four passive house demonstration projects, a good way to gain knowledge about how to build energy efficient buildings. The results expected from this research projects is to find guiding principles and tools needed for passive house planning, not only describing project specific solutions but to make the system solutions usable for planning in more general terms, and also study the possibilities and limitations of energy efficient buildings in a Swedish perspective and climate. Joining as a part of the planning group, advice and help is given to architects, consultants and to the client. In the planning process, general advice and concept solutions can be developed. Lack of components, systems and planning aids can be

identified. The demonstration projects are located in the south west of Sweden. Three of the projects are new constructions and one is a renovation project.

In the centre of Värnamo in the southern part of Sweden, 40 rental apartments were built in 2005/2006 according to the passive house standard as a part of the public housing sector. The apartments are distributed in five buildings; two with two storeys and three with 2.5 storeys. All five buildings have solar collectors on the roof connected to a central room for domestic hot water production, one in each building. Additional heat for domestic hot water is supplied from an electric battery in the accumulator tank. Every apartment has its own mechanical ventilation system with heat recovery. The ventilation air flow at normal settings is around 30 l/s in the two and three room apartments and 40 l/s and 45 l/s in the four and five room apartments. With an indoor temperature of 20°C the peak load for space heating is calculated to 8.3 W/m². The space heating demand is then calculated to 9.82 kWh/m²,a. If the indoor temperature is 22°C the peak load for space heating is calculated to 9.1 W/m² and the space heating demand is calculated to 12.8 kWh/m²,a. In Derob-LTH thermal bridges are not taken into consideration. Additional energy demand caused by thermal bridges must be added to the calculated result. The client invited tenders for the project according to the law of public tendering. The large contractor NCC got the all- in - one contract. The building company NCC was responsible for purchasing the sub-contractors. Before the major work started at site, everyone involved were gathered for an afternoon with education. Models of the roof, outer wall and ground construction were made and placed at site. The ground work of the five houses started with excavation, followed by macadam spread out on the bottom of the hollow. Insulation to stabilize the construction was put on the macadam under the load bearing plinth. To avoid thermal bridges, two L-elements were put outside the plinth for thermal insulation. The walls in the load bearing structure were made of concrete and cast at site. The exterior walls were made of wooden frame construction and mounted at site. The wooden roof construction was mounted at site. On the initiative of the contractor, one apartment was measured according to air-leakage at an early stage to know if the building method used gave the set-up air-tightness. This measurement of air-leakage in the construction was performed by the carpenters. After the measurements, the contractor could finish all apartments, having measured values for the specific construction and not only a feeling of doing right. The final measurements when the buildings were finished showed an average air leakage of all buildings of 0.2 l/s m². It was hard to find an entry door on the Swedish market that has a U-value of 0.6 W/m²K. Therefore, the general manager of Finnvedsbostäder made an own door construction and produced it at one of the largest Swedish door companies. The gross amount per square meter, subsidies not subtracted, ended up at 17 898 SEK/m². The total cost for the contractor was 36 700 000 SEK, VAT not included; approximately 11 800 SEK/m². In these prices, the cost for the piece of land is included and costs for electricity- and water connections. The difference between the cost for the client and the cost for the contractor shows that there is a large cost for the design stage.

The passive house project in Frillesås consists of three houses built as a part of the public housing sector in two storeys. They contain 12 rental apartments with two, three and four rooms with either a balcony on the upper storey or a patio on the ground floor. The ceiling height is 2.6 m. There is a separate central for technical equipment and separate garage buildings. The air is supplied by mechanical ventilation with an air to air heat exchanger, one in each apartment, placed in the kitchen. During cold periods space heating is supplied in the supply air duct by a water heating battery of 1.0 kW. The domestic hot water is prepared by solar collectors and auxiliary heat is supplied by district heating. There are

about 52 m² of solar collectors mounted on the roof of the apparatus building. Both the regular windows and the bathroom windows have a total U - value of 0.7 W/m²K according to the producer. The ventilation flow is at its highest settings 50 l/s per apartment. If the indoor temperature is 20°C the peak load for space heating is calculated to 8.5 W/m² and the energy needed for space heating is calculated to 9.6 kWh/m²,a. When simulating the building with an indoor temperature of 22°C the peak load for space heating is calculated to 9.4 W/m² and the energy needed for space heating is calculated to 12.6 kWh/m²,a. Additional energy demand caused by thermal bridges must be added to the calculated result. The ground work started in November 2005. The concrete slab on the ground was founded on a layer of macadam and insulated with polystyrene insulation. Separating the two storeys in each building is a prefabricated filigree system of beams. The measurement of the relative humidity in the filigree system of beams showed high moisture content in the concrete. To avoid building in too much moisture, the drying process was closely followed. The load bearing structure in the internal walls were prefabricated and made of an insulated steel beam construction, covered on both sides with gypsum board. The exterior walls were prefabricated and completed at site. On the inside, plastic foil sealed the construction and was covered with wooden frames together with insulation. On the outside, the wooden facade material was mounted on wooden frames attached to the polystyrene. The wooden panels are primed at the factory before mounted. The gypsum boards in the walls are protected from moisture in the construction by ending the boards a bit above the concrete. After finishing the walls, the roof was mounted and covered with roofing-felt. It is a wooden construction, sealed with plastic foil between the apartments and the attic. The attic is not mechanical ventilated, but ventilated by two air vents. All sub-contractors involved in the project need to take the importance of air tightness seriously. Holes made in the climate shell by another contractor should not need to be fixed by the carpenters. Everyone needs to take their responsibility. The total average air leakage in the three buildings is 0.19 l/s,m². The total production cost of the apartments and the garages are approximately 14 500 SEK/m². This includes the piece of land, connections for water and sewage system, connection to district heating and VAT. The time to finish this project at the building site was 10 - 11 months. The constructional drawings were very general, no detailed drawings were made. One of the carpenters said that a detailed drawing might have been used for the first construction, then it would have been ignored and a more suitable way of construction found out by the carpenters would have been used. Now, he says, the more suitable way of construction was chosen directly. Experiences show that a short but informational text about passive houses should be an introduction in the document when inviting tenders to give an offer. This is important not only for the information but also because it affects the price. The time for making the buildings air tight needs to be considered in the bid. When you rent an apartment from Eksta Bostads AB, you always have a personal meeting with a representative from the client. That makes it easier to transfer information about living in a passive house.

In Lidköping close to Lake Vänern, a single-family house has been built with passive house standard. The client wanted a new built house with a low need of maintenance and a low energy use. The family found information about passive houses on the internet and thought it would be suitable for their wishes for a new home. In the summer of 2004 the family got in contact with Vårgårdahus, a small company that builds wooden-frame single-family houses. They thought building a passive house was something in line with their company's values of high quality buildings with a low energy use. The planning process resulted in a house in two storeys with a total living area of 170 m². The room height is 2.6 m at the ground floor and at the upper floor it is a sloped ceiling, going from 1.8 m to 3.5 m height.

The house is heated by air. The air is supplied with an air-to-air heat exchanger. The heat exchanger has an efficiency of heat recovery of approximately 85 % according to the producer. The ventilation rate is 0.5 ach, with the kitchen fan not connected to the heat recovery system. Additional heat for the supply air is distributed by a waterborne heating battery with a capacity of 2.5 kW. During the planning process, it was important to assure that it would be practically possible to build the house in the factory with the available devices. If the indoor temperature is 20°C the peak load for space heating is calculated to 9.2 W/m² and the energy needed for space heating is calculated to 15.2 kWh/m²,a. When simulating the building with an indoor temperature of 22°C the peak load for space heating is calculated to 10.1 W/m² and the energy needed for space heating is calculated to 19.6 kWh/m²,a. Additional energy demand caused by thermal bridges must be added to the calculated result. Before the work at site started, half a day of education was held at Vårgårdahus. The ground work started in May 2006 and the construction work continued in October 2006. It took 5 days to mount the house. Some complementary work was needed, but more or less 5 days. A normal house from Vårgårdahus in two storeys usually takes 2 days to mount at site. The groundwork started in the end of May 2006. Since the piece of land is clay, the ground work was reinforced by 12 driving piles. The ground was then filled up with macadam, polystyrene insulation and a concrete slab on top. The load bearing structure was prefabricated and made of wooden frames. An iron beam is complementing the structure on the ground floor. The internal walls are a wooden frame construction with mineral wool, covered on both sides with gypsum boards. The blocks in the exterior walls contain of a wooden frame construction with mineral wool, each made in two parts, mounted at site with a polystyrene layer between. The façade material is wood panel, primed with iron vitriol mixed with silver stain. The windows had a total U-value of 0.71 W/m²K for the fixed windows, and 0.85 W/m²K for the operable windows. The glass, the distance between the panes and the gas in the gaps are the same in both windows. This glass combination is also used in the terrace doors and gives then a total U-value of the doors of 0.95 W/m²K. The windows were mounted at site. The polystyrene was cut out in the window openings, angling the window bays to get more light into the rooms. In the openings, nailing plates are holding the three wall sections together. The outer roof construction has a slope of 10°, from the south façade to the north façade. The roof is covered with steel decking mounted directly on the roofing felt, insulated with loose wool insulation followed by a wooden frame construction insulated with mineral wool. Below, there is a layer of wooden panelling and then the ceiling material. The ventilation unit was placed in a separate room together with the connection to the district heating. The domestic hot water is supplied by district heating. A measurement of the air tightness of the building shows a result of 0.44 l/m²s. The required air tightness was 0.2 l/m²s, thus not fulfilled in these first measurements. Before the surface material on the ground floor was laid, the client ordered a measurement of the moisture content of the slab on the ground to make sure the levels of humidity in the concrete was sufficiently low. The final cost of the house is not yet summarized. The costs will be more closely discussed in the final thesis.

Alingsåshem, the public housing company in Alingsås owns 300 apartments in the Brogården area. The apartments in Brogården were built in 1970 and are in great need of renovation. The brick façade is worn out, the ventilation is not working satisfactory and the apartments are not suitable for elderly or disabled persons. The tenants complain about draught and low indoor temperature. The apartments will be renovated aiming to the energy levels of a passive house. The general manager at Alingsåshem divides the renovation cost in three. One part is energy saving, the second is the higher standard in the apartments (larger bathroom, new surface materials

etc) and the third is the maintenance cost, the cost for the renovation anyway needed. Since the need of renovation was so extensive, the cost for making the building energy efficient is not dominating. The building is in three storeys with two stairwells. Three apartments on each floor share stairwell. The load bearing structure is made of concrete. The outer walls consist of an insulated wooden beam construction, with brick as the surface material. During the renovation process, following measures will be taken:

- Thermal insulation on the ground floor and the outer walls
- Acoustic insulation on inner walls
- New façade material
- New windows
- Increase air-tightness, building envelope
- Move balconies
- Entrance vestibules
- New ventilation with heat exchanger
- Energy-efficient household appliances
- Solar collectors for domestic hot water
- Individual monitoring; DHW and house hold electricity

During fall 2007 the planning process in the Brogården project proceeds. The building process, measurements and results will be presented in the final thesis in 2009.

Additional analyses of the buildings in the three new built projects were made in Derob-LTH. In the one family house, indoor temperature variations were simulated to see differences between using wood as the load bearing construction, compared with using concrete. The results of these simulations show that there are a total of 733 hours when the indoor temperature in the house is higher than 25 °C, using the wooden beam construction. The highest indoor temperatures are received on the second floor, where there are a few hours above 32°C. The total calculated number of hours in all volumes when the indoor temperature is above 25°C using the concrete construction is 611h. Then the calculated indoor temperatures do not exceed 28 °C. Villa Malmborg is also used to see theoretically what happens to the indoor temperature if no one uses the house during two cold days in February. Simulations are made using first the wooden beam construction and then the concrete construction, assuming in both cases that the sun does not shine at all. The calculated mean values of the indoor temperature using the wooden beam construction vary much during the days. The indoor temperature using the concrete construction is much more even. Comparing the mean values of the indoor temperatures in the wooden beam construction and the concrete construction, it clearly shows that the temperature in the concrete construction falls less than the temperature using a wooden beam construction. The mean values in the volumes using the wooden beam construction is falling from 20°C to approximately 7°C, when the mean values of the temperatures in the concrete construction is not falling below 10°C.

The outer walls in Frillesås were prefabricated and insulated at site with polystyrene insulation on both in and outside. The general contractor uses this method of building outer walls in regular project but with less insulation. Normally 50 mm of polystyrene insulation is used on the outside, 195 mm mineral wool in the wooden beam construction and 45 mm mineral wool on the inside in the space for installations. The outer wall construction regularly used by the general contractor is used for simulations in Derob - LTH, to see if these outer walls with less insulation can be used regarding the demands on the peak load for space heating.

The heat load for space heating using the wall with less insulation is calculated to 11 W/m². This exceeds the passive house criterion of a peak load for space heating of 10 W/m². Using the passive house construction, the calculated peak load for space heating is 8.5 W/m². With an indoor temperature of 20°C the calculated total need of energy for space heating is 3151 kWh/year, using the passive house construction. Using the regular construction with less insulation, the calculated energy demand is 4868 kWh/h. The difference in the calculated total need of energy for space heating is 1717 kWh/year. To find the optimized passive house construction, both regarding peak load for space heating and investment costs, different insulation thicknesses should be tried in simulations.

When heating a building with the supply air the supply air temperature must not exceed 52°C. To avoid draught and noise problems in the ventilation system the ventilation rate should be limited to the levels of hygienic flow, anyway needed to fulfil sufficient indoor air quality conditions. One of the multifamily houses in Värnamo is simulated in Derob - LTH to see what supply air temperatures are needed to keep an indoor temperature of 20°C without raising the ventilation flow and if these temperatures exceed 52°C. According to the climate data regarding Jönköping used in this simulation, the coldest period in the year is from the 24th of February to the 2nd of March. The results from the first simulation shows that, with an indoor temperature of 20°C, the supply air temperatures never reaches 52°C in any of the volumes of the building. When the indoor temperature is increased to 22°C in the simulations, the supply air temperature rises. The supply air temperature in Volume 8 will be higher than 52°C for 3h. To achieve an indoor temperature of 24°C using comfort ventilation rate, the supply air temperature needs to exceed 52°C for 85 h.

To reduce the energy consumption in buildings in Sweden, it is important that these demonstration projects are seen as something positive and will become duplicated. A non-functioning project group will probably not build something similar again. To build passive houses might be associated to be complicated and time-wasting with many factors of uncertainty. Well accomplished demonstration projects are seen as reference objects and are used as a base in future projects. The project leader has here a key role. The proud carpenters with straight backs are priceless as advertisers for building passive houses. During the working process with the three new built passive house projects it turns out that the leadership differs much between the project leaders. The three classical types of leadership are all represented in these demonstration projects. In the project with the democratic project leader, the structure in the project is kept by closely following the set up agenda. The authoritarian project leader is keeping the structure in the project by strict orders, where everyone knows who is doing what and when it needs to be done. The third project leader is working somewhere between a democratic and a laissez-faire way of leading his project, using diplomacy to everyone involved in the project. Will the different ways of leadership affect the final result? Can a certain way of leadership be the difference between success and failure in a demonstration project? Is there some way of leadership to prefer when building a demonstration project? Trying to answer these questions, the four project leaders in the three new built projects were interviewed regarding their leadership.

As a project leader it is important to know precisely what to order and what actions to call for at the contractors. In these demonstration projects many new actions, not regularly used in building projects, needed to be purchased and coordinated.

Experiences show that proper set up demands are very important to get a hold of these new actions and to reach the goal of a well functioning passive house. Everyone working with the building must know what they are

doing and why. Initial education prevents the project from disruptions and makes everyone at site working in the same direction. If only one contractor do not participate in the initial education, this can cause later delays in the project, when this contractor's work has to be redone. In a demonstration project, the knowledge in the project team is built up along the way. To be able to develop the knowledge needed in these demonstration projects it was important to have the right competence in the planning group. One project leader says that the competence might have been too low in their project. This did not affect the final result, but the additional support from the project leader has taken much time from the planning process that could have been used in better ways. It is important to be prepared for unexpected incidents when making something new. In these demonstration projects the unexpected events have been solved in different ways. Sometimes it has been enough for the project leader to have a discussion with everyone involved and together solve the problems. Another way for the project leader to deal with the unexpected events has first been to first closely examine the size of the problem and after that investigate if the problem could be solved and how. To not be alone about the decisions, an external contact, with for instant previous experiences of building energy efficient buildings, can be used to discuss these kinds of problems. One of the project leader says that it is of major importance to act as fast as possible when you as a project leader sees signals of something unexpected that has occurred. Experiences in these demonstration projects show that one important thing that prevents the unexpected incidents to be discovered is that people hope to solve their own problems. The person it concerns tries as long as possible to keep the problem to himself and not ask for help or advice. It has shown to be very hard to admit a mistake or a lack of knowledge. To make it easier to early ask for advice, it is very important to have an open climate in the working group where signals like this is received in a good way. The project leader must focus on finding the best solutions for the project, not finding the scapegoat. Earlier studies have shown that in solid projects, the authoritarian project leader that concentrate on the result has worked very well. In a more unstable environment, the focus must be more on persons and democracy. It seems like a pilot project could equal to an insecure project, according to earlier research, in need of a firm but democratic project leader.

The authoritarian project leader might not be the best leadership in a pilot project. Then there is a great risk that the participants in the project group do not dare to show their lack of knowledge due to a great respect for the project leader. Instead of reporting mistakes to the project leader, the contractors try to solve the problems themselves. It is important to early in the project reveal if it something one does not understand to minimize the consequences of mistakes made in the project that can affect the final result.

The one of the demonstration projects that run most smoothly had a well updated project leader that could easily answer questions and by that run the project forward. If the project leader does not know what is expected from him, he is insecure regarding taking important decisions. To wait for decisions cause a lot of frustration among the contractors. This frustration can be avoided if the project leader early knows what he has authority to decide about.

Lack of good leadership might also cause sickliness in the planning group or in the contract group, when people feel frustrated or gets too much responsibility that they are not supposed to have.

It is still possible to build demonstration projects with good results even if the project leader does not lead the project idyllically. Skilled contractors and external experts can together create a very good final result. It is expensive to do changes late in the project. Lack of good

leadership might not affect the final result but the final cost. If the budget is tight, money might be taken from something that increases the quality to cover the additional expenses. If a temporary solution has a shorter lifetime will show after the houses are used for a while.