Deep renovation of older multi storey building blocks – Sems Have

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SUMMARY

Denmark is participating in IEA Annex 56 "Cost Effective Energy and Carbon Emissions Optimization in Building Renovation" with the case-study Sems Have. The buildings in Sems Have have undergone deep energy renovation in order to reach an energy consumption corresponding to the Danish "nearly zero energy buildings" definition, i.e. Building Class 2020 according to Danish Building Regulations.

This paper describes the energy renovation in detail along with calculations and measurements of energy use before and after the renovation. The project has demonstrated that the extra investment necessary in moving from Low Energy Class 2015 to Building Class 2020 is 0.3 % of total expenses.

KEYWORDS

Energy, Renovation, Building Class 2020, Nearly Zero Energy Buildings

INTRODUCTION

Denmark is participating in IEA Annex 56 "Cost Effective Energy and Carbon Emissions Optimization in Building Renovation". The main objective is to provide tools, guidelines, recommendations, best-practice examples, and background information to support decision makers, in the evaluation of the energy efficiency, cost effectiveness and acceptance of the renovation measures towards both the nearly zero-energy and nearly zero-emission objective.

Sems Have was chosen as a Danish case study for IEA Annex 56, see Figure 1.

Figure 1. Sems Have before renovation.

Sems Have was originally built in 1973, but underwent a minor renovation in 1995 where new windows were added and the insulation level of the exterior walls was increased. Before the recent renovation the energy label of the buildings was C corresponding to between 86 - 136 kWh/m^2. The gross heated floor area before the renovation was 3,300 m^2 and after the renovation 3,626 m^2.

The buildings are owned by the housing association Boligselskabet Sjælland and originally consisted of two blocks; Block A (left in Figure 1) containing a day-care centre at the ground floor and a dormitory at 1st to 3rd floor. Block B (right in Figure 1) containing a day-care centre at the ground floor and a hall for e.g. music at the 1st floor. The buildings were rented by the municipality, however, when the municipality terminated the lease, the housing association were left with buildings that could not be rented out.

Instead of just modifying the buildings for repurposing the housing association decided to use the buildings as a showcase demonstrating that it is possible to perform economically sound deep energy renovation to nearly-zero energy. The Danish definition of nearly-zero energy is less than 20 kWh/m^2 primary energy for residential buildings including heating, ventilation, cooling and domestic hot water.

The recent renovation was initiated October 2012 and finished December 2013. The buildings simply could not be let out for their original purpose (dormitory and day-care centre) and therefore it was decided to convert the buildings into 30 low energy apartments instead.

Figure 2. Sems Have after renovation.

The background and main reasons for the renovation and conversion of the buildings into 30 low energy apartments can be summed up as follows:

- Conversion as the buildings could no longer be let out for the original purpose
- Improved thermal envelope – walls, roofs and windows
- Balanced mechanical ventilation systems with heat recovery
- New (district) heating system
- PV system for reaching nearly-zero energy (Danish Building Class 2020)
- Improved architecture.

The renovation was financed like new social housing, i.e. not subsidized.

DESCRIPTION OF THE ORIGINAL BUILDINGS

The renovation of Sems Have included improvement of the thermal envelope, i.e. walls, roof and windows, installing a new and highly efficient balanced mechanical ventilation system with heat recovery, installing a new heating system (district heating) and adding a PV system in order to reach the nearly-zero energy level according to Danish Building Regulations (Danish Enterprise and Construction Authority, 2010), i.e. Building Class 2020. The renovation of Sems Have also significantly improved the architecture of the buildings which is quite clear if you compare Figures 1 and 2.

Before the renovation, the buildings were rated at energy class C buildings, and therefore the energy demand actually was not the reason for the renovation. The buildings were renovated since they could not be rented out due to their layout and because they were more or less worn down.

Originally both blocks had a loadbearing internal concrete construction with panel walls containing 125 mm mineral wool. In 1995 a 100 mm mineral wool was added to the walls, i.e. a total 225 mm. The windows installed in 1995 were double glazed with a U-value of 2.8 W/m^{2}K. The roof of block A had 200 mm mineral wool. The horizontal part of the roof of block B was insulated with 150 mm mineral wool while the mansard part of the roof was insulated with 125 mm mineral wool. The basement walls below ground had no insulation whereas the part above ground had 50 mm mineral wool. The floor slab in the basement had 200 mm expanded clay aggregate below the 100 mm concrete slap.

Before the renovation the buildings were heated by district heating with an indirect two-line radiator circuit. Domestic hot water was stored in a 2,500 litre tank insulated with 100 mm mineral wool.

The day-care centre and the halls (in block B) were ventilated by balanced mechanical ventilation with heat recovery below 60 %. The dormitory and the basements had natural ventilation.

Figure 3. Block A (left) and block B (right) before renovation.

ENERGYSAVING MEASURES

As mentioned earlier the renovation of Sems Have included a repurposing of the buildings from day-care centre and small dormitory flats to 30 up-to-date and affordable apartments of 67-145 m^2. The new apartments meet the requirement for Danish Building Class 2020, i.e. corresponding to the Danish definition of nearly-zero energy buildings with an energy use of maximum 20 kWh/m^2 primary energy for heating, ventilation, cooling and domestic hot water.

The renovation included stripping the buildings down to the internal loadbearing concrete structure. The only other construction left intact was the roof of block A. The mansard part of the roof of the 1st floor (hall) of block B was replaced with vertical walls identical to the other walls of the buildings and new pitched roofs were added in order to allow for 400 mm insulation. The hall at the 1st floor of block B was divided into 7 apartments with an extra floor in part of the apartments leading to an increase of the total gross floor area of the buildings of approx. 10 %. The living rooms are of double height. Table 1 shows the U-values before and after the renovation.

Most of the facades were stripped from the building along with the roof of block B. New facades with a U-value of 0.20 W/m^{2}K and a roof with a U-value of 0.09 W/m^{2}K were added. The roof that was not stripped was refurbished to 0.09 W/m^{2}K. The new triple glazed windows have a U-value of 1.0 W/m^{2}K. Balanced mechanical ventilation systems with heat recovery replaced a combination of old ventilation systems and natural ventilation. The new ventilation systems have a heat recovery rate of 84 % and an electricity use for air transport of 2.0 kJ/m^3. Finally, two arrays of PV panels with a nominal power of 17.3 kWp (in total 117 m^2) were added on the roofs. Figure 2 shows the buildings after renovation.

The buildings were fitted with a new district heating substation, new radiator circuit, two new domestic hot water tanks of each 1,000 litres with a heat loss coefficient of 3.7 W/m^{2}K and new domestic hot and cold water piping.

The staircases have low energy lighting systems using LED and low energy fluorescent tubes.

Table 1. Building envelope after renovation.

Element	Area after retrofit m^2	U-value before retrofit W/m^2K	U-value after retrofit W/m^2K
Panel walls	1,497	0.20*	0.20
Gable walls	224	0.30*	0.30
Windows/doors	568	2.80	1.00
Roof	1,043	0.20 – 0.32	0.09
Floor over basement	970	2.30	1.10

* The U-value before renovation was actually quite good but the walls were worn down and needed replacement and therefore the new walls U-values are the same. Also, using the same amount of insulation in the new walls as in the old kept the total gross area of the building at the same level.

In order to reach the level corresponding to Building Class 2020 renewable energy was needed and therefore two PV systems totaling 117 m^2 with a performance of 17.3 kWp were added to the roofs.

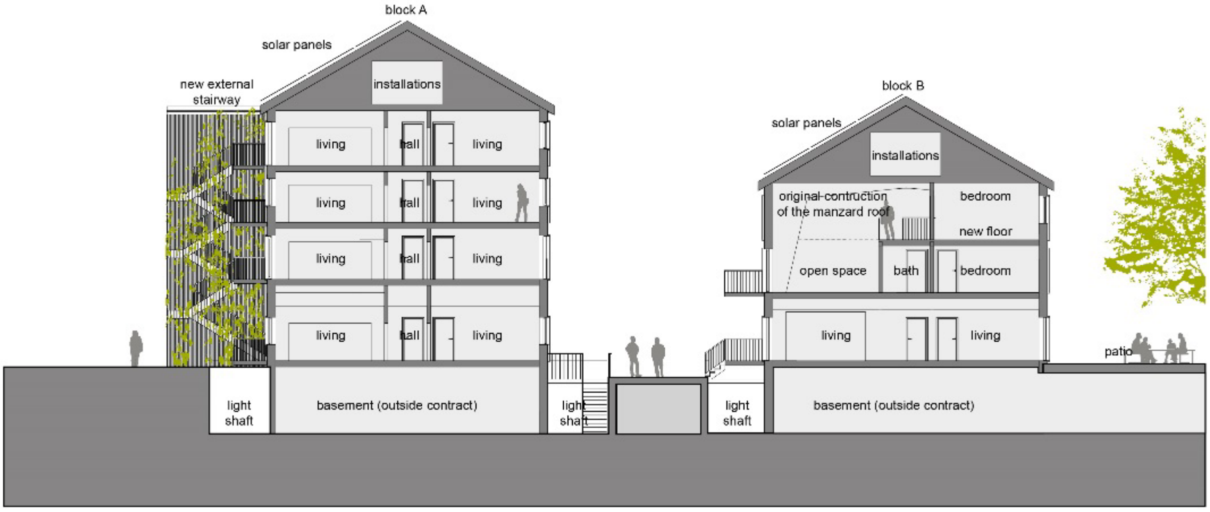

Figure 4. Cross section of block A (left) and block B (right) after the renovation.

ENERGY CONSUMPTION AND SAVINGS

Energy consumption for space heating and hot water before the renovation was measured. During the planning of the renovation the expected energy consumption for space heating and hot water was calculated and since the project was finished in December 2013 measurements of the actual energy consumption has been carried out with monthly readings.

In order to meet the requirements for Building Class 2020 the Danish compliance checker Be10 (Aggerholm and Grau, 2014) needs to be used for the calculations. Table 2 shows a summary of the Be10 calculation results.

Table 2. Energy consumption for heating, ventilation, cooling and domestic hot water (Be10).

Energy consumption	kWh/m^2 gross area
Net mean space heating demand:	9.4*
Net mean domestic hot water demand:	13.7
Building related electricity demand:	6.0
Electricity production from PV panels:	3.6
Primary energy demand minus PV production:	16.2
Requirement Danish Building Class 2020**:	20.0

* Basements not included in heating demand
** The primary energy factors for Building Class 2020 are 0.6 for district heating and 1.8 for electricity.

The district heating consumption for both buildings incl. basement before renovation was measured as 508 MWh/year which included the heat losses from the basement. The expected energy consumption after the renovation was calculated as 179 MWh/year also including the heat losses from the basement. Therefore, the expected district heating savings are 329 MWh/year corresponding to 65 %.

Before the renovation the electricity demand for ventilation was measured as 57 MWh/year. After the renovation the electricity demand for ventilation is calculated as 20 MWh/year, corresponding to savings of 37 MWh/year. The expected electricity production by the new PV system is 13 MWh/year.

Measurements of the energy consumption were performed in 2014 (18.12.2013 – 1.1.2015). The total energy consumption for heating and domestic hot water was 234 MWh. The monthly measured data are shown in table 3. During the same period the total water use was 2,602 m^3. Electricity use for common areas and ventilation system was measured as 22,640 kWh (13 % higher than expected) and the production by the PV systems on the roofs of the buildings were 17,907 kWh (38 % higher than expected), i.e. covering almost 80 % of the common electricity use.

Table 3. Measured energy consumption for heating and domestic hot water in MWh.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Energy	25,8	22,8	22,8	20,3	18,4	15,9	12,5	15,2	16,1	18,1	21,2	24,7	233,7

Figure 5. Sems Have after the renovation. The façade cladding is slate plates.

The indoor climate in the buildings also improved significantly due to the installation of the balanced mechanical ventilation with heat recovery but also because of the reduction of heat loss and draught through windows and doors. The indoor climate will be monitored during the summer of 2015 and winter 2015/2016.

RENOVATION COSTS AND SAVINGS

As mentioned earlier, the buildings had to be severely renovated or demolished as they could no longer be used for their original purpose. At first, the housing association wanted to renovate according to Low Energy Class 2015 (voluntary low-energy class in BR10), i.e. 30.5 kWh/m^2. However, as Building Class 2020 (20 kWh/m^2) would only cost 232,000 DKK (31,000 EUR) or 0.3 % extra - for PV systems, better windows and extra 60 mm insulation on the roof - it was chosen to go for the Building Class 2020 instead.

Table 4 shows the total expenses for the project.

Table 4. Expenses for the renovation project.

Expense	million DKK / million EUR	kDKK/m^2 / kEUR/m^2
Craftsmen	44.31 / 5.91	12.20 / 1.63
Consultants	5.19 / 0.69	1.43 / 0.19
Various building project costs*	22.89 / 3.05	6.30 / 0.84
From 2015 to 2020	0.23 / 0.03	0.06 / 0.01
Total	72.62 / 9.68	20.00 / 2.67

* Repayment of old loans, building owner fee, municipality and state charges and fees, stamp duty for a new mortgage etc.

The reduction of energy use expected in Sems Have will result in total savings of 324,000 DKK/year (43,200 EUR/year). Table 5 sums up the different parts of the energy savings achieved. No comparison has been made yet between measured (actual) and calculated (expected) consumption in the after situation. These comparisons will be performed as soon as the data has been collected.

Table 5. Total energy savings (based on measurements before and calculations after).

	MWh/year	DKK/year / EUR/year	DKK/m^2 per year / EUR/m^2 per year
District heating	329	214,000 / 28,533	59 / 7.9
Electricity for ventilation	37	81,000 / 10,800	22 / 2.9
PV electricity production	13	29,000 / 3,867	8 / 1.1
Total	329 + 50	324,000 / 43,200	89 / 11.9

CONCLUSIONS

Two buildings containing a dormitory, day-care centre and a hall were successfully transformed to up-to-date nearly-zero energy residential apartments. Only the concrete structure and the insulation of the roof (the latter in one building) were preserved. The preservation saved both money and CO_2.

The renovation has resulted in up-to-date affordable apartments which can be rented out by the housing association (there is a waiting list to get an apartment). Furthermore, the renovation has improved the architecture and indoor climate of the buildings and the buildings now have a new sewer system, new cold and hot-water system and new electrical system. There are new lighting in the staircases, new kitchens and bathrooms, balconies for some of the apartments, elevator to the upper apartments in block A and improved surroundings. The users are very content with the quality and layout of the apartments, the indoor climate, the improved architecture and the surroundings.

The renovation was financed like new social housing, i.e. not subsidized. The rent of the apartments is comparable with other apartments of the same quality in the area. The experience of the housing association – Boligselskabet Sjælland – is that it is a good idea when performing deep energy renovation to strip the building down to the loadbearing constructions and add a new thermal envelope instead of trying to improve the original thermal envelope. However, they also learned that it is a challenge to upgrade existing buildings to contemporary and future-proof apartments especially if the new design uses other module lines etc. than the original design.

The concrete structures (including decks) were maintained, however, this made it difficult to comply with modern requirements regarding acoustics. PCB, asbestos and paint containing lead had to be removed from the building and safely deposited. The housing association also experienced difficulties in obtaining approval from the municipality to change the status of the buildings from dormitory/day-care centre to residential.

The new improved apartments and architecture has been very well received by the tenants. There is at the moment a waiting list for people who would like to rent an apartment in the buildings.

The indoor climate and the energy use of the buildings will be followed closely in the coming years and the results will be utilized for promoting deep energy renovation of multifamily buildings in Denmark.

The Sems Have renovation was nominated for the renovation award Renover 2014.

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