TREES **Training for Renovated Energy Efficient Social housing**

Intelligent Energy -Europe programme, contract n° EIE/05/110/SI2.420021

Section 3 Case studies

3.2 Dunaújváros, Hungary

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Contents

The German-Austrian-Hungarian Solanova project aims at the realization of the renovation of a demonstration building with passive house measures. In the frame of the project a pilot building was renovated. The works were finished in October 2005 in Dunaújváros, Hungary.

1. INTRODUCTION

Buildings made with prefabricated technology face significant problems in the building stock of Eastern-Europe. In Hungary 20 % of the dwellings belong to this cathegory. The buildings represent a low quality standard regarding energy consumption, operating cost, thermal comfort and fabric protection.

The construction of buildings made with industrialized technology dominated the housing sector from the middle of fifties till the end of eighties all over Europe, but especially in Eastern Europe and the Sowiet Union. Only in Hungary there are 780 thousand of these kind of flats (20% of the building stock), which is lower than the average of the post communist countries. In the former Eastern Germany there are appr. 2,2 millions of such flats.

Figure 1: The Solanova building before renovation

Figure 2 The Solanova building after renovation

The category of buildings made with industrialized technology contain the so called “panel buildings”, but also those living-houses, which were bulit by other type of industrialized technology (e.g. block-, cast-, tunnel-shuttered-, ferro-concrete skeleton-houses). For simplifications in the paper the name “panel buildings” will be used for all these categories.

Panel-rehabilitation is currently a most actual question of the region, because the expected lifetime of the holding structures are still above 50-100 years, whereas the windows, building finishes and building service systems have reached the end of their physical lifetime.

Furthermore the panel buildings are criticised for their high heating energy consumption, uncontrolable heating systems, very poor thermal comfort especially in summer, low acoustic value, untight building envelope and building physical problems. All these result in the most pressing problem: the declining welfare of the inhabitants.

The Solanova project aims at the demonstration of the energy conscious renovation of an existing panel building (in the followings the building will be called as “Solanova building”, see Fig. 1 and Fig 2) using passive house measures and solar energy support. In the German-Austrian-Hungarian project the special charateristics of the panel buildings are examined and the already worked out passive house measures are applied. The original state and the impact of the renovation are examined by a scientific supervision and a computer aided monitoring.

The renovation process ended in October 2005, but the scientific research and the demonstration finished in December 2006.

2. TARGETED BUILDING PERFORMANCE

Heating energy consumption: The heating energy consumption of the original building was 210 kWh/m^2/year in the heating season 2004-2005. It is a measured value corrected for a mean winter season. The contractual Solanova target was to decrease this value under 45 kWh/m^2/year.

Summer thermal comfort: The climate in Hungary is continental, the winter is cold, the design temperature for heating systems is from –15 to -11 ^{o}C depending on the region. On the other hand, the summer is hot and dry, the temperature can exceed 35 ^{o}C and the yearly solar radiation is 4,42 GJ/m^{2}year.

A social research made among the dwellers in the Solanova building before renovation proved that the biggest problem after the high operation costs was the poor summer comfort. Thus, the improvement of the summer comfort was essential in the Solanova renovation concept.

Winter thermal comfort: Due to the uncontrolable heating system of the original building the difference in the mean indoor air temperatures in the flats with different locations was very high before renovation.

In the rooms located at the end facades having two or three exposed surfaces the air was 5-6 ^{o}C colder than other rooms with more protected position. A significant improvement of the winter comfort was expected from the new controlable heating system and the balanced ventilation.

DHW and solar energy use: If the heating energy consumption is reduced with 80-85 % (as expected) the heat demand of the domestic hot water would have a significant share. It would be approximately double of the heat demand. Therefore measures were made to reduce the DHW consumption and to support the DHW production with renewables.

The location of the building is ideal for using solar energy, because one main façade faces to the South and there are no shading obstructions in front of the façade, only a one-storey nursery school.

Eco-efficiency: The project can be successful only if the measures are replicable, therefore low cost solutions were developed during the optimisation process. Ecologic aspects were also in focus, all measures were analysed for a whole life cycle.

Satisfaction of tenants: Engagement of users in decision making was also important, because experience from another social housing project proved its positive feed-back. [1] A social research followed the demand of the dwellers and the acceptance of the low-energy concept. The satisfaction of them was an essential issue, because this is a key point to the attractivity of the demo building.

3. APPLIED TOOLS

The studies, calculations were supported by several tools. The most important ones are as follows:

- WinWatt heat loss calculation tool.
- Dynbill dynamic simulation tool (Passivhaus Institut)
- Heat2 thermal bridge calculation tool
- Pleiades+Comfie dynamic simulation tool (in co-operation with E-co-Housing project)
- Ecoinvent, the Swiss database of life cycle inventory
- Sunbil process chain model, including the relevant processes of each craft, the maintenance and the energy consumption (The description of Sunbil was realized with the software tool Umberto)
- Solar model for optimising the collector system
- Building integrated monitoring system
- Movable data loggers (Testo and Hobo)
- Blower door tests
- Smoke generator
- Thermographic camera
- Laboratory experiments of the ventilation system
- Questionnaires and interviews

4. THE BUILDING CONCEPT

4.1 Measures reducing the transmission losses

In order to achieve the targets the building envelope had to be insulated and new energy efficient windows were installed. A special feature of the panel buildings is the sandwich structure: the original prefabricated panels consisted of two reinforced concrete layer and 5-8 cm thermal insulation in between. Therefore the major heat loss related to the joints, in fact the thermal bridge losses were generally higher than the losses calculated from the U-value.

Figure 3: The facades were covered with 16 cm polistyren thermal insulation

Figure 4: Planting on the green roof

It means that the external insulation of the facade has much more impact on the thermal bridge losses than on the U-value. Therefore it was enough to apply less thermal insulation than in other low energy buildings. In the Solanova building 16 cm PS thermal insulation were applied on the facades, more wouldn't have had much sense (Fig. 3).

The flat roof was covered with 21-34 cm thermal insulation and the cellar ceiling with 10 cm (Fig 6).

For architectural reasons and to create a recreation area for the dwellers a green terrace roof were constructed aiming an additionnal positive effect on summer comfort in the top floor dwellings (Fig. 4 and 5).

The old, extremely bad revolving windows were installed to new energy saving, but not passive house windows.

Calculations proved that on the southern side the energy balance for the whole heating season is approximately the same for double and for triple glazing, because although the heat losses are higher for double glazing the solar gains are higher, too. For the northern side the triple glazing is definitely better.

Nevertheless, for cost restrictions on the northern side double glazing windows were installed with a U_w-value of 1,4 W/m^{2}K. Contrarily on the southern side for summer protection reasons triple glazed windows with integrated shading devices were applied with a U_w-value of 1,0 W/m^{2}K, due to the higher priority of summer comfort.

Thermal bridge free installation of windows was essential (Fig. 7).

Figure 5: View from the neighbouring building

Figure 6: Insulation of cellar ceiling with 10 cm PS

4.2 Air tightness

If the building envelope is well insulated further savings can be achieved by decreasing the ventilation losses. In the Solanova building a balanced ventilation system with heat recovery was installed. It can work at the design efficiency level only if the building is extremely air tight. In passive houses the n_{50} value must be lower than 0,6 h^{-1}.

Certainly this is not the aim, but in the original building the air tightness was very poor. The blower door tests measured n_{50} = 7,1..12,0 h^{-1}.

4.3 Windows and summer protection

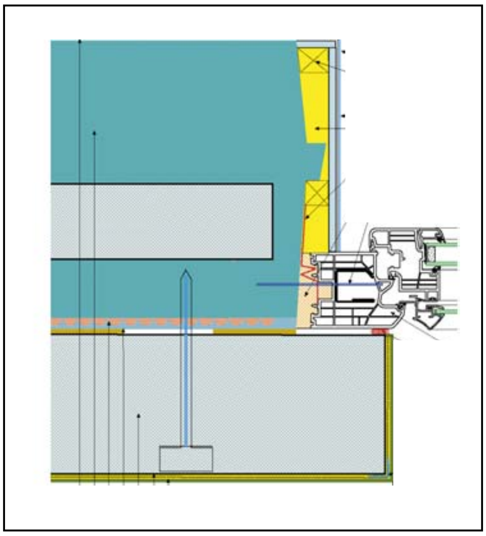

Figure 7: Thermal bridge free installation of the triple glazed windows on the southern and western side. [4]

As it was proven by the social research, a good summer indoor climate is perhaps more essential than the energy saving. Although the yearly cooling load is usually moderate compared to the heating load, air conditionning units use electric energy that has a triple primary energy coefficient than gas or heating oil.

Dynamic simulation models [1] (Pleiades+Comfie and Dynbill) predicted that the application of efficient shading devices and natural night ventilation would be enough to keep the daily peak indoor air temperature below the acceptable 26 °C.

Analysing different shading possibilities, internal shading was excluded, due to the poor efficiency or high price. External shading didn't seem to be optimal either, because the thermal bridge free installation would have increased the price and there is a strong wind in the area.

The final solution was a movable shading device with lamellas integrated between the two external glass layer of the window. It is almost as efficient as the external type and there are no problems of wind and instalation.

4.4 Heating and ventilation system

The ventilation losses were decreased by flatwise balanced ventilation systems with heat recovery. The remaining heat demand are covered by a new ordinary radiator system. It is a double pipe system with minimised total pipe length, small radiators and roomwise control.

The optimisation process proved that the main problem of designing a heating system in a low-energy building is the avoidance of overheating.

Figure 8: Installed ventilation heat recovery units under the ceiling of the hall. Now they are covered with gypsum board suspended ceiling.

Figure 9: Installed solar collector field on the southern canopy.

4.5 Solar collectors and water saving devices

Without any measures the heat demand of the DHW would have had a dominating role after the retrofit. Therefore water saving equipments were installed and 72 m^2 solar collectors support the DHW production. The collector field serves double function: in addition to the DHW production they perform as a canopy for the southern ground floor shops providing shadow and rain protection (Fig. 9) [5].

5. EVALUATION

5.1 Energy

The monitoring proved that the targeted energy savings were achieved. The heating energy consumption of the building before renovation (average of the two previous seasons) was 2100 GJ. After renovation it decreased to 394 GJ (season 2005-2006). It means 81,3 % energy saving. This figure is in the range of 80-85% predicted by the simulations.

In specific values the consumption dropped from 213 kWh/m^2a to 39 kWh/m^2a (the targeted level was 45 kWh/m^2a). Fig. 10 shows the performance of the flats and the shops separately. Whilst in the flats 35 kWh/m^2a was measured, in the shops its double, 71 kWh/m^2a, because no heat recovery ventilation was installed in the shops and the glazed ratio is higher.

The monthly energy consumptions can be seen in Fig. 11. The diagram was made in January 2007, therefore data from that month on are not indicated. As explained in the following sub-chapter, the tenant overheated the building significantly. If they kept the temperature lower (e.g. at 22 ^oC that is still pleasant) there wouldn’t be any need for heating in October and April, so the heating season would be 30-50 days shorter than that for ordinary buildings.

A main result of the added thermal insulation was the significant drop of the thermal bridge losses, because previously the insulation thickness was much less at the joints than in the sandwich panels. Fig. 14 shows the evidence of it though thermographic photos.

Fig. 13 illustrates the final energy flows of the SOLANOVA building before and after the refurbishment. The upper diagrams clarify the reduced consumption after the refurbishment. While the amount of electricity did not change very much the demand of energy for heating and hot water was reduced up to 13% and 26% respectively. The share of heating energy in the total energy consumption became smaller after the refurbishment. Before the refurbishment the share was 82%, after the refurbishment it was 70%. The lower Sankey diagram illustrates the reduction of fossil final energy consumption to 16% after the refurbishment by the saving of heating energy, hot water and the supply of solar energy.

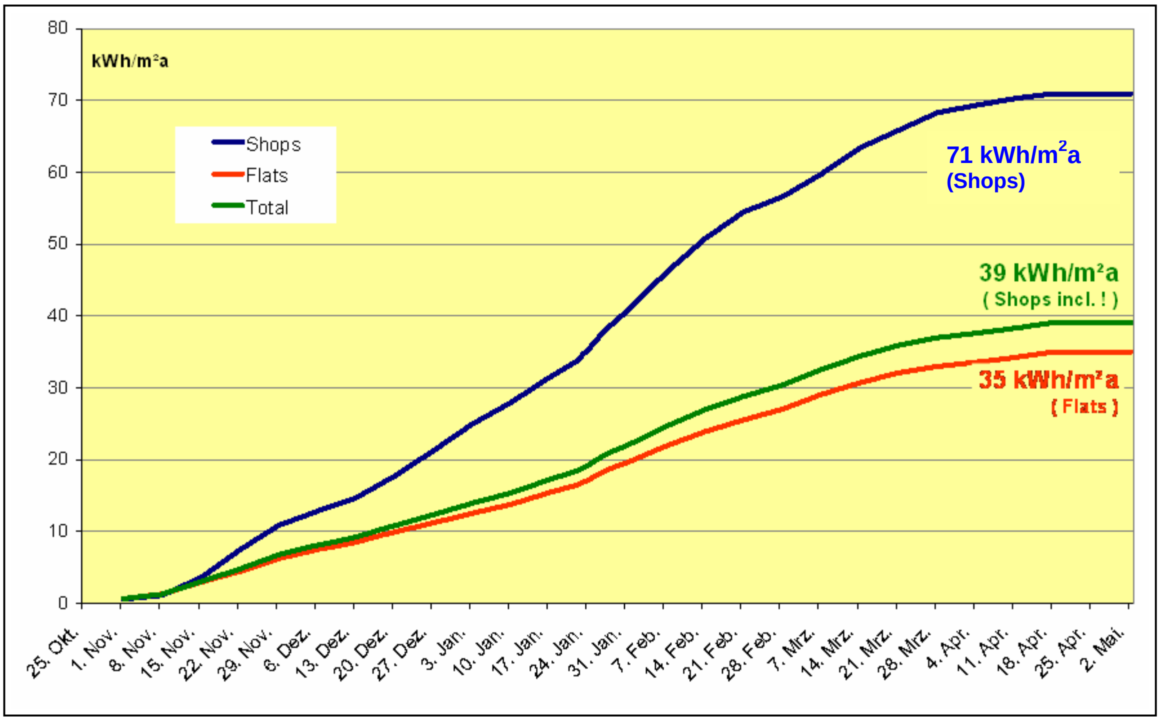

Figure 10: Cumulated heating energy consumption in the heating period 2005/2006

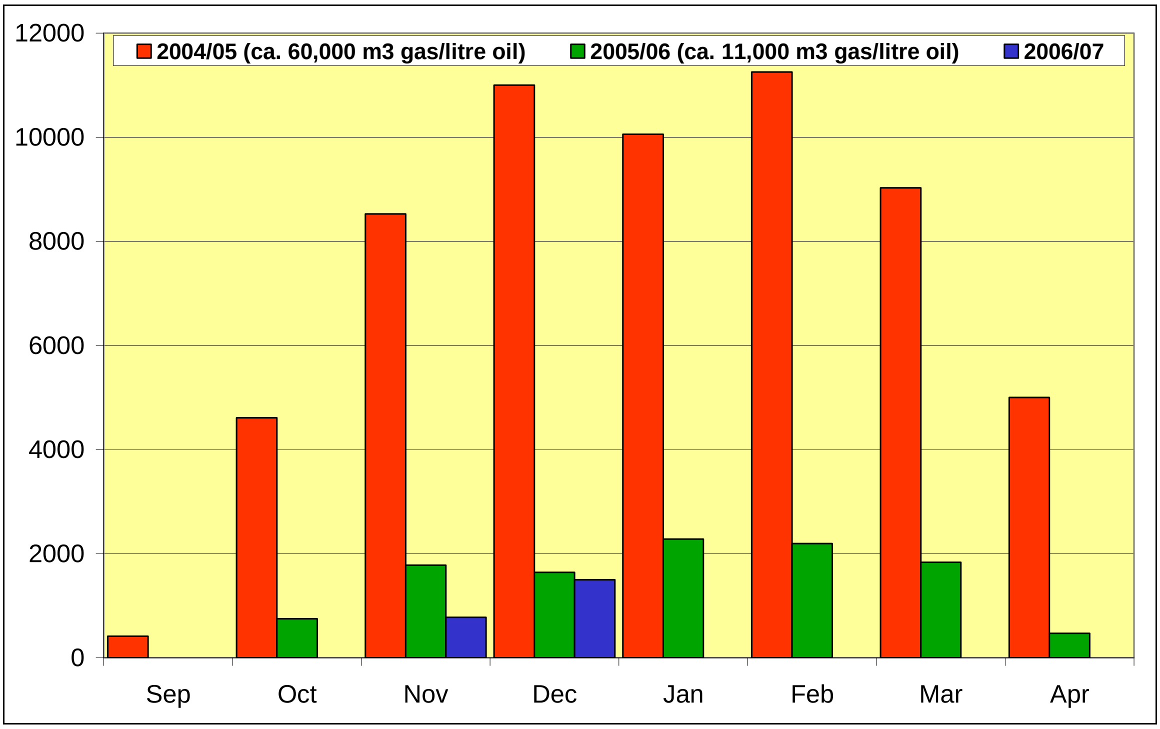

Figure 11: Monthly heating energy consumptions before (heating period 2004/2005) and after (heating periods 2005/2006 and 2006/2007) renovation

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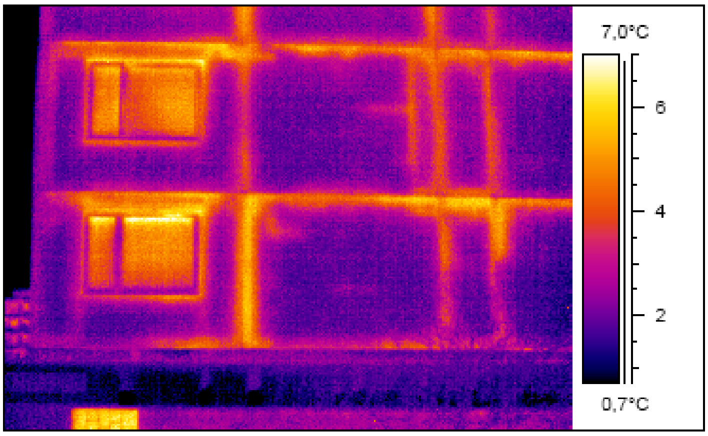
T külső/T outside	-0,8°C



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T külső/T outside	-3,5°C

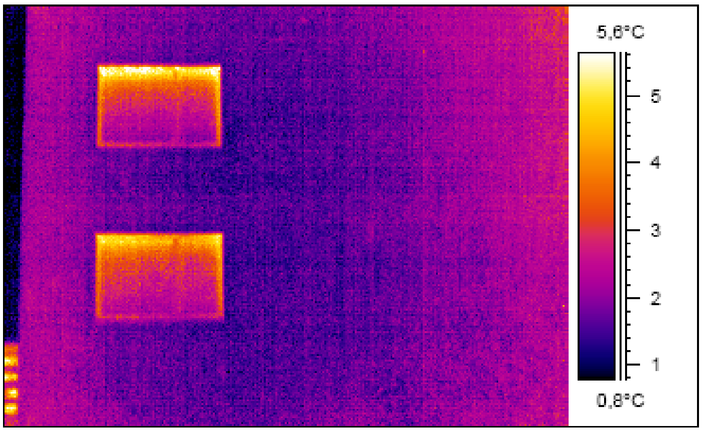

Figure 12: The quality control of the building envelope with thermography.proves that the thermal bridge losses are minimised

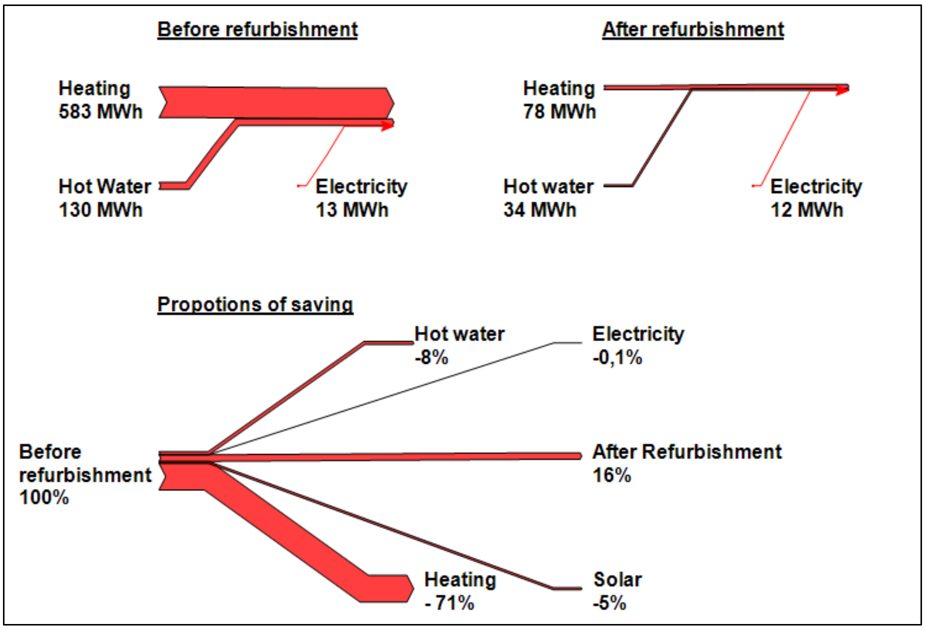

Figure 13: Sankey diagrams of the final energy flows before and after refurbishment

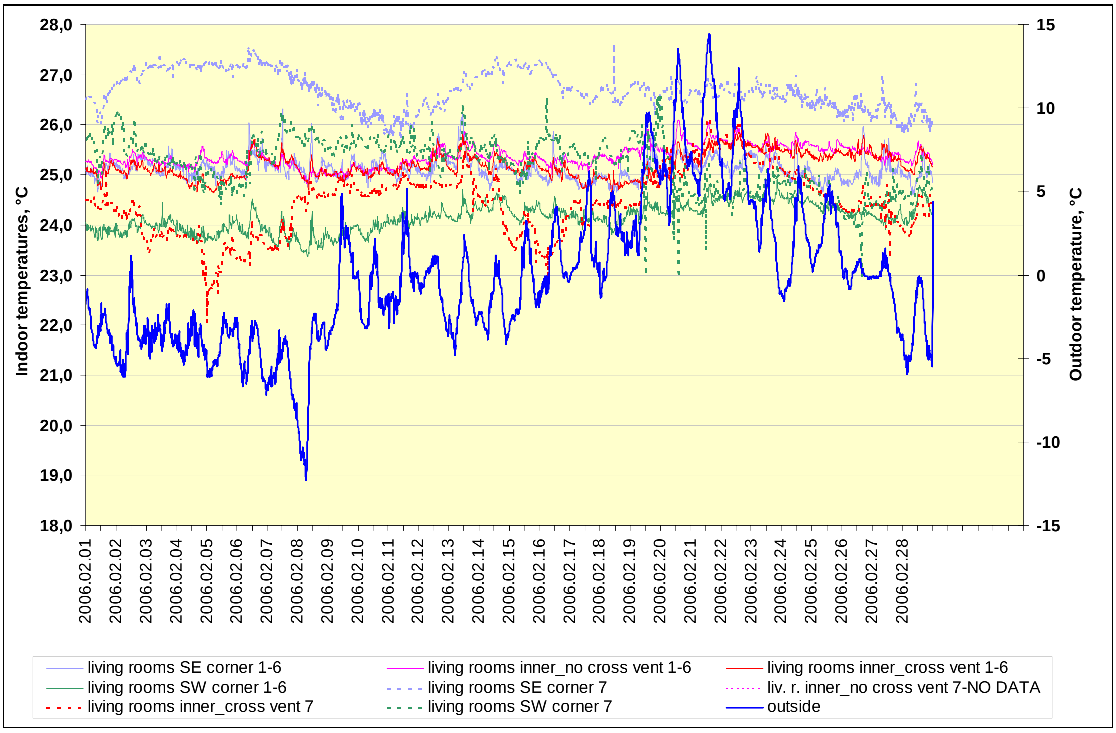

Figure 14: Registered air temperature in the living rooms groupped according to location during February 2006.

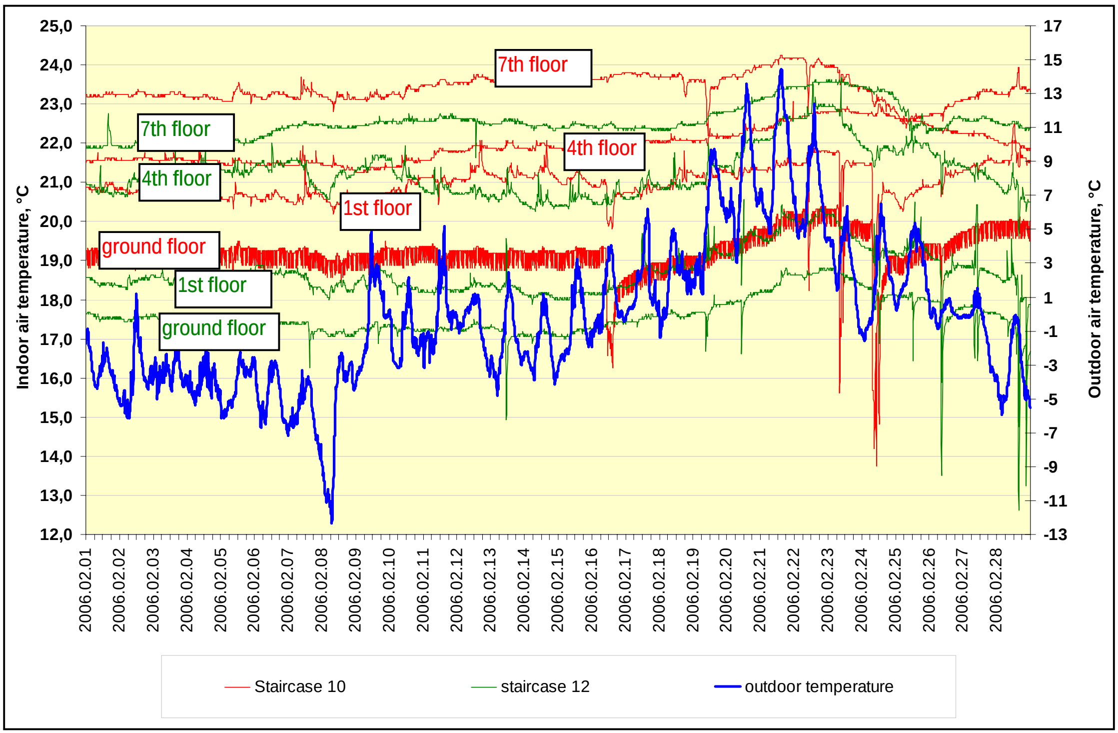

Figure 15: Registered air temperature in the two unheated staircases during February 2006.

5.2 Thermal comfort

5.2.1 Winter

The building integrated temperature and humidity sensors regisrated the temperature every 5 minutes during one year before renovation and two years after renovation. The evaluation of the winter data proved that the thermal comfort in rooms with all different locations are highly acceptable: there are no underheated rooms, unlike before renovation. However, as the energy costs decreased radically, the tenants do not show any willingness to operate there systems in an energy efficient way: the indoor air temperatures are measured to be significantly higher than the standard values (Fig. 14). The average temperature in February 2006 was 24,7 °C. It includes the unheated staircases, but not the ground floor and the cellar.

The high temperatures in the staircases (Fig. 15) prove that the heat cost allocation in a well insulated building cannot be correct: if someone doesn't want to pay for the heating he can turn the heating off and the temperature will still be acceptable.

The relative humidity, which was to low before renovation (15-25%), also increased to the comfort range: 30-45%.

5.2.2 Summer

Comparing the indoor air temperatures in rooms with different locations before (Fig. 16) and after (Fig. 17) renovation it can be noticed that whilst before renovation even daytime the temperatures were often higher then the outdoor temperature, after renovation they were definitely lower than the peaks.

Although the improvement of the summer comfort is evident the results could be even better as it is explained the ”Social research” chapter.

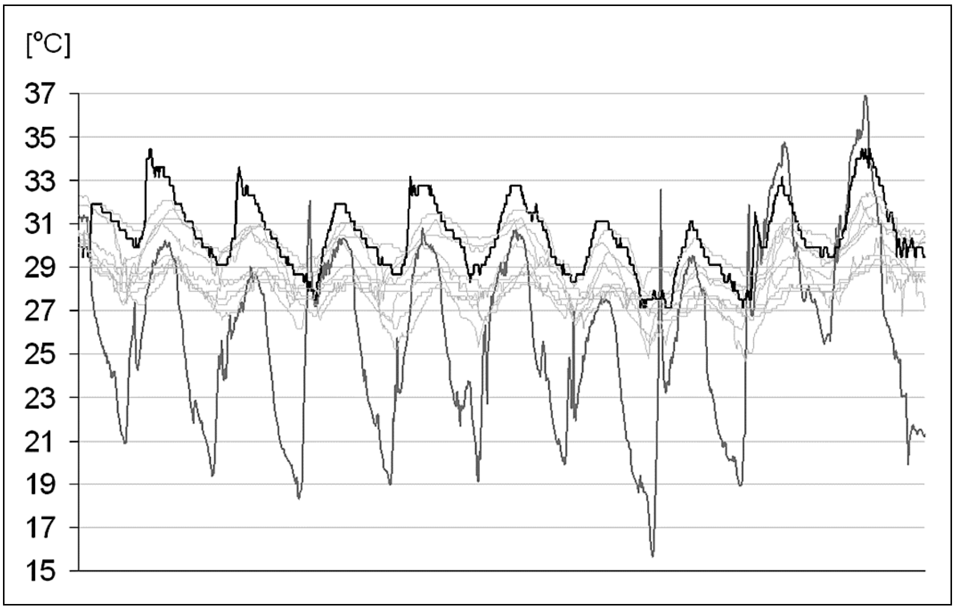

Figure 16: Indoor air temperature in rooms with differerent locations in a period of 10 days before renovation. The outdoor temperature is the bold curve with larger amplitudes.

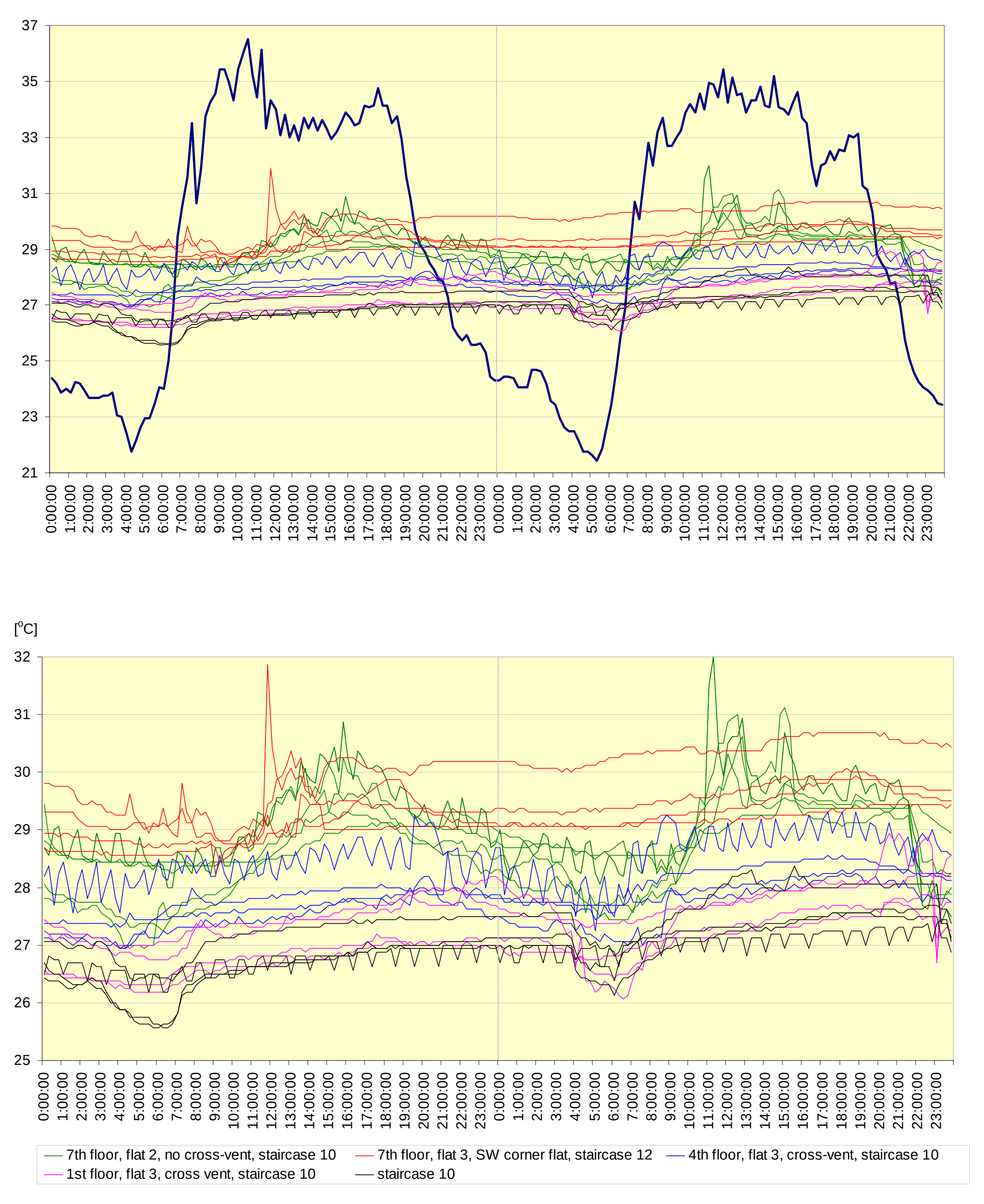

Figure 17a-b: Registered air temperatures in characteristic points of the building in the two unheated staircases during the two hottest days (22-23 July) of 2006.

5.3 Social research

5.3.1 Behaviour

Behavioural aspects have to be divided between summer and winter. The “optimal” behaviour for achieving maximal comfort with minimum energy requirements was communicated to the dwellers by a “handy winter guide” (two pages) and a “handy summer guide” (1 page). Based on these guides all dwellers were personally tought the “optimal” behaviour either in their own flat or in another flat in the SOLANOVA building.

5.3.2 Winter

In *winter* the most critical parameters are a) window opening, b) setting of the ventilation unit, c) setting of temperature and d) use of venetian blinds. Item a) was checked with the help of observations and questions during the surveys. Altogether the dwellers reduced the former extensive window opening to a very little, adequate extent, which has not affected the energy consumption significantly. The same positive statement is valid for b). Almost all dwellers used the ventilation unit in balanced mode which is necessary for utmost heat recovery and minimal energy consumption. More critical are c) and d). The average temperature in the heating season 2005/06 was close to 25°C. This is remarkably high but apparently intended by the dwellers who have the possibility to control the temperature by means of thermostatic valves in each living room. Compared to a temperature level of 19°C this results in almost 50% more space heat consumption, compared to 20°C in ca. 40% more consumption. Nevertheless the space heat consumption in 2005/06 was below 40 kWh/m^{2}a, which is unique for this kind of building. In SOLANOVA there are no heat cost allocators, because they wouldn’t operate correctly in a well insulated building, they probably would result in lower temperature levels – but maybe only for one or two seasons. Secondly, which is more important, the dwellers could be convinced about 25°C not at all being a healthy temperature level in winter. At 25°C, 30% relative humidity (RH) is quite common in the SOLANOVA building on a cold winter day. This is the low end of the acceptable bandwidth. At 20°C the RH would rise to 40% which is much healthier. In SOLANOVA very effective venetian blinds have been installed to provide for good summer comfort. Unfortunately, occupants use the blinds very much in winter during day. This keeps out the sun, which is the most important heating source. Maybe heat cost allocators would make the dwellers change this habit, too.

5.3.3 Summer

In *summer* the most critical parameters are a) the use of venetian blinds, b) window opening and c) setting of ventilation unit. According to dynamic simulations proper use of the venetian blinds could reduce the indoor temperature by ca. 2 K. The majority of the dwellers gives away this opportunity. As the thermal coupling between the flats in the SOLANOVA building is very strong, dwellers, who adapt their behaviour, do not see a clear benefit; their effort will be compensated by their overheated neighbours. Night cooling has to be managed by sufficient opening of the windows at night. For experimental purposes we removed two frequently mentioned barriers for effective night ventilation: a) we installed mosquito nets at all window wings that were meant for natural ventilation (the river Danube is very close) and b) we installed small very easy to handle fixations for these wings to stimulate the dwellers not to tilt the windows, which is almost useless, but to sufficiently open them around the vertical hinges without the danger of an “auto-mobile” wing. In a nutshell: the positive effect of these efforts was disappointing. Observations and the results of the 3rd survey indicated a strong “misbehaviour” which partly led to unforced overheating in the building, although we had distributed a small *one* page guide with all necessary information and each dweller was *personally* explained what to do. Most occupants open the windows at the wrong times or they tilt the windows, which only yields marginal cooling effects. The right setting of the ventilation unit during day and night can both support the natural ventilation and keep the heat out. From personal interviews it got obvious that this was done quite sub-optimal, too.

In a nutshell, we conclude, that the behavioural change which is necessary to provide for comfortable summer conditions is much harder to achieve than a suitable winter behaviour.

There is a very big potential to avoid energy intensive air-conditioning by passive measures and suitable behaviour.

5.3.4 Satisfaction

Altgogether, the dwellers' satisfaction with the new living comfort is overwhelming. Although from engineers point of view the behaviour is far from being “perfect”, especially in summer, people rate several aspects of the SOLANOVA building very high. Even the satisfaction with the flat increased considerably, although a retrofit only changes some of the relevant determinants. Naturally a very high satisfaction with temperature in winter was reported. The satisfaction with temperature in summer also increased sharply. Compared to the situation before, even the “misbehaviour” of the dwellers could not completely eliminate the physical advantages of the building. All in all, we conclude, that SOLANOVA really matches the needs of the dwellers, as their reported satisfaction and rating is very high.

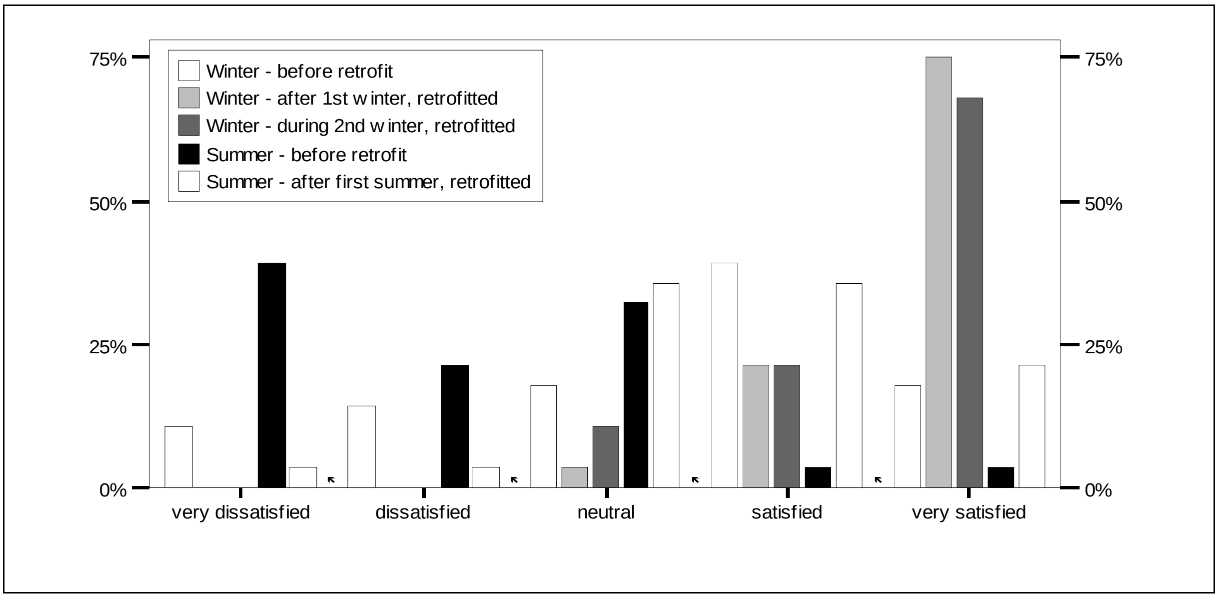

Figure 17: Satisfaction with flat

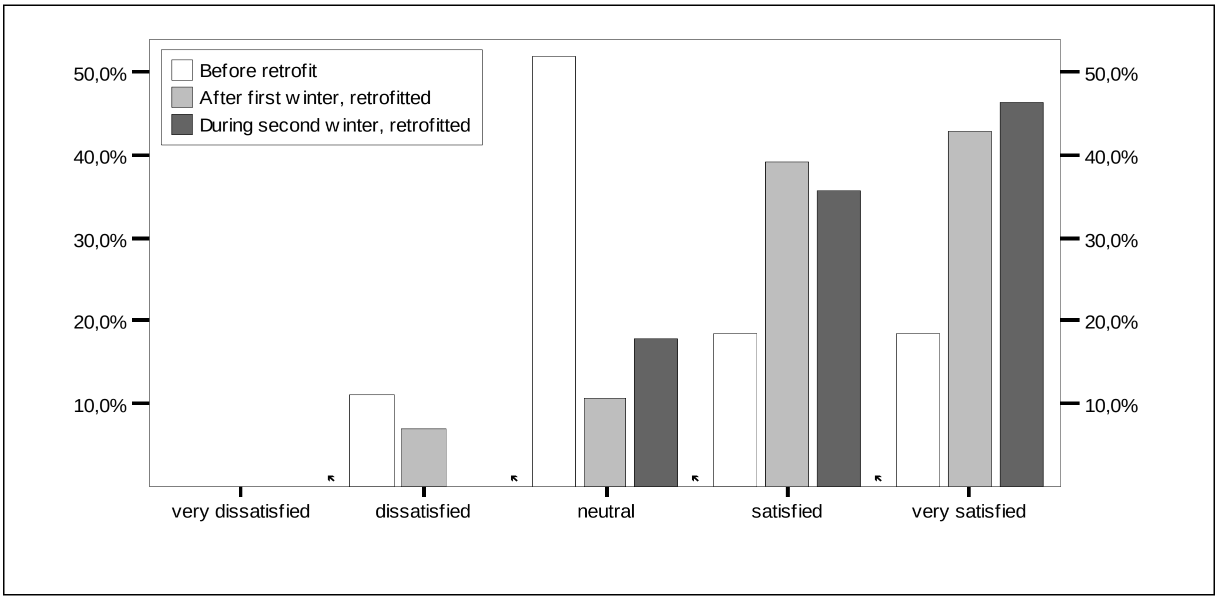

Figure 18: Satisfaction with temperature

5.4 Costs

A further interesting analysis was the comparison of the investment for and the benefit of the refurbishment measures (see Figure 19). Therefore the minimal and maximal investment in cent per saved kilowatt hours was investigated. Depending on the basic assumptions the investment laid between 2.4 and 2.7 ct/kWh for a period of 40 years. The benefit was made up of the avoided energy cost. The avoided energy costs of the supply of district heat were defined as 2.8 ct/kWh to maximal 4.5 ct/kWh (assumed an increasing of the energy price at 60% till 2008). Further aspects which can be considered are the trade of CO_2 certificates and the profit by the increased comfort of the flats.

The specific cost of the investment was 18 707 euros/flat (323 euros/m^2 living area).

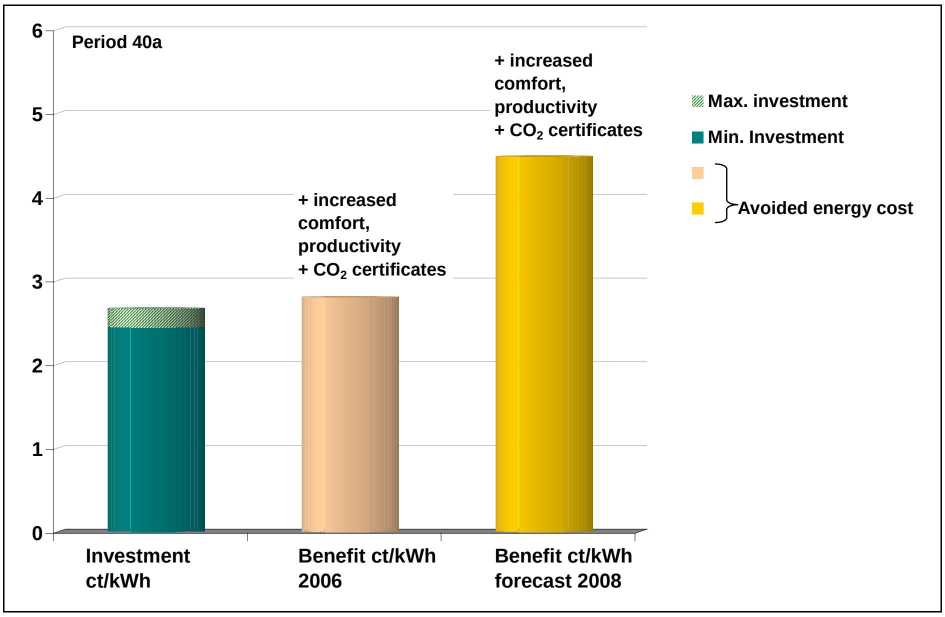

Fig. 19: Investment and benefit of the refurbishment measures in cent/kWh

6. CONCLUSION

Solanova serves as best practice example for the proper implementation of the European Union's Energy Performance of Buildings directive. Ongoing renovations of the huge stock of large residential buildings not only in Eastern Europe, where alone more than 100 Million people live in panel buildings, only result in minimal non-sustainable improvements. In order to achieve sustainable improvements, Solanova proposes a symbiosis of three strategies:

- design for human needs
- optimised resource efficiency of the building
- optimised solar supply.

In 2005, after two years of thorough research and preparations, one 7-story-panel-building in the Hungarian town Dunaújváros has been transformed into Europe's first 3-litre-panel-building by consequently applying the ultra-low-energy-building-philosophy to an extent, which was judged to be best practice for retrofit. Overnight solar energy provides more than 20% of the total consumption for space heat and domestic hot water. Mainly this is due to a drastic decrease of space heat consumption, which was measured to be more than 80% already in the first winter.

7. ACKNOWLEDGEMENT

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