Ulm-Böfingen: Retrofitting of Catholic Community Centre using Vacuum Insulation Panels

1. Photo

Figure 1. Community hall from the south.

2. Project Summary

Over 90% of all building projects of the diocese Rottenburg-Stuttgart with an annual investment from about 40 million Euros are for renovating existing buildings. With the retrofitting of the community centre “Zum Guten Hirten” they would like to show what the church can do to help protect the environment. One of the targets set was to at least halve the energy consumption. The project had to be financially viable as well as functional. For the project three buildings on the site were renovated. They were the community hall, the kindergarten with apartments and the rectory with offices. One of the prerequisites was that the external appearance of the community hall should not be altered. In view of the many different functions and times of usage in the rooms an easy to use room temperature control system was also a requirement. Figures 1 – 3 show the retrofitted buildings.
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Key features of the retrofit concept are

- Photo voltaic collectors
- Vacuum insulation panels (see Figure 4)
- Solar collectors for heating domestic hot water
- Windows with low U-values
- Single room temperature control
- Low energy lighting

Figure 2. Kindergarten from the east

Figure 3. Rectory from the south
3. Site

Ulm is a university town in Baden Württemberg, Germany. It lies on the banks of the Danube River under the southeastern foot hills of the Schwäbischen Alb. The suburb Böfingen overlooks Ulm from the northern side.

- Altitude 490 m
- Mean annual temperature 9.1 °C
- Mean winter temperature 4.1 °C
- Climate description: Sunny, temperate, Würzburg test reference year
- Heating degree days (based on 20°C) – 4269 Kd
4. Building Description / Typology

4.1 Typology / Age
The catholic community centre “zum Guten Hirten” was built in three phases. The first was in 1966 when the church and the community hall were erected. In 1974 the kindergarten and rectory were built. The kindergarten has two levels with the top level being three self-contained apartments. The rectory has offices on the middle level and an apartment upstairs. On the lower level are to be found storage rooms, an office and the house utilities room. In 1990 the building of the bell tower completed the third phase.

4.2 General information

Community Hall

<table>
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<th>Year of construction:</th>
<th>1966</th>
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<tr>
<td>Year of subject renovation:</td>
<td>2004</td>
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<td>Total floor area (m²):</td>
<td>769 (with apartment 887)</td>
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<tr>
<td>Occupant capacity:</td>
<td>10 to 50 users per day - 2 in apartment</td>
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Kindergarten

<table>
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<th>1974</th>
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<td>Year of subject renovation:</td>
<td>2004</td>
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<tr>
<td>Total floor area (m²):</td>
<td>337 (with apartment 482)</td>
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<tr>
<td>Occupant capacity:</td>
<td>30 to 40 per day - 3 in apartments</td>
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Rectory

<table>
<thead>
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<th>Year of construction:</th>
<th>1974</th>
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<tbody>
<tr>
<td>Year of subject renovation:</td>
<td>2004</td>
</tr>
<tr>
<td>Total floor area (m²):</td>
<td>329 (with apartment 329)</td>
</tr>
<tr>
<td>Occupant capacity:</td>
<td>3 employees per day - 1 in apartment</td>
</tr>
</tbody>
</table>
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4.3 Original Building

The community hall is a two storey reinforced concrete construction. The external walls are made of 24 cm thick concrete. In some areas the walls of the lower level have a layer of 11.5 cm sand-lime bricks in front. Some other wall areas (both levels) on the inside were lined with 3 cm insulation panels. The U-values lie between 0.83 W/m²K and 4.70 W/m²K. The flat roof was insulated with a 6 cm insulation layer. In the lower level between the floating floor and the concrete fundament are 3 cm insulation panels. The U-value being 0.95 W/m²K. The windows had wooden framing and a U-value 2.5 W/m²K.

The kindergarten construction is a mixture of in-situ concrete and prefabricated components. The roof and upper floors are built on concrete beams which run from inside to outside and pose problems as thermal bridges. Three apartments make up the upper level while the kindergarten is in the lower level. The apartments cover approximately 40% of the kindergarten. The flat roof and windows are the same as described above for the community hall. In front of the upper level’s reinforced concrete wall is a curtain wall. The 5 cm space is filled with insulation panels. The lower level’s walls are insulated on the inside with 3 cm panels.

The rectory is also a reinforced concrete construction. There are three levels. The exterior walls for the two upper levels are constructed from an inner layer of 14 cm concrete, a 6 cm insulation layer of polystyrene and an outer layer of 7 cm concrete. The U-value is approximately 0.55 W/m²K. The 24 cm thick reinforced concrete walls of the lower level have a layer of 3.5 cm thick insulation panels. Inner walls from heated to non-heated zones are only partly insulated. The flat roof has an insulation layer of 6 cm. The U-value being 0.57 W/m²K. The windows are similar to the other buildings and in the floor of the lower level is a layer of 3 cm insulation. In Figure 6 can be seen the site plan while in Figures 7-9 the buildings before retrofitting can be seen.
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**Figure 7. Community hall before retrofit**

**Figure 8. Kindergarten before retrofit**
One problem was the large energy losses due to the long and poorly insulated piping between the buildings and losses in the heating transfer station. Another problem was the openings in the building envelopes. A Blower door test for the kindergarten (without apartments) measured an air change by 50 Pa of 4.8 ACH. The main problem was around the window frames and at the ceiling connection to the outside. In the rectory 3.1 ACH was measured with the main contributor to the air leakage being the windows, external blinds and sliding doors.

5. Previous Heating, Ventilation, Cooling and Lighting Systems

The buildings of the community centre are heated by district heating. The delivery takes place in the installations room in the community hall. The house installations are connected directly to the district installations without heat exchangers between. From the installations room the church, kindergarten and rectory are then supplied. The pipes are either in installation shafts or run directly through the earth. In all buildings the heat is distributed with radiators. In the church is additionally floor heating. In the rectory is a 130 l DHW tank while in the kindergarten there is a 200 l DHW tank which is for the three apartments as well as the kindergarten. The DHW tanks are both located in the installation rooms of their respective buildings and heated by the district heating. In the community hall both apartment and hall DHW heating is electric. In Figures 10 & 11 can be seen the heating and DHW distribution system pre-retrofitting as well as recorded heat consumption.
6. Retrofit Energy Savings Features

6.1 Retrofit Concept
The concept was the theme of an architectural competition. The energy reduction aims were set as an outline for the competition. After the competition the draft plans from the architect offices Günter Hermann and Gesellschaft für bauphysikalische Objektplanung (GFO) were used as the basis for the final conception. In the final conception planning the following institutions and offices took part:
- Katholische Kirchengemeinde „Zum Guten Hirten“, Ulm-Böfingen
- Fraunhofer-Institut für Bauphysik, Stuttgart (IBP)
- Bayrisches Zentrum für angewandte Energieforschung e.V. (ZAE Bayern), Würzburg
- T.P.I. Trippe + Partner, Karlsruhe

Figure 10. Heat energy distribution with results of pre retrofit measurements

Figure 11. Heating energy demand pre retrofit
The ZAE Bavaria was responsible for the planning and installation of the vacuum insulation panels, whereas Trippe + Partner was responsible for electric and heating installations. Over several workshops including IBP and representatives of the community centre Ulm-Böfingen the final planning took place. The calculated heating energy demand was made by GFO. In Figures 12 – 21 can be seen floor plans and cross sections from all three retrofitted buildings.

### 6.2 Retrofit System Description

For the community hall insulation could only be added to the inside of the external walls as a prerequisite was that the exterior facades remain untouched. Additionally there could be no change to the inner side of the foyer north wall, as no change in the room usage was possible. Only the walls under the windows on the south side could be removed. The apartment was left untouched. On the inner side from the exterior wall 10 cm mineral wool replaced the existing insulation. The replaced south side walls received a rear ventilated curtain facade with 10 cm insulation. The roof insulation was replaced with 22 cm hard foam insulation panels. In the lower level of the building apart from the corridors all the floors were renewed with an insulation thickness of 7 cm. The windows were replaced with wooden framed double low-E glazed windows.

The entrance area of the three apartments over the kindergarten was closed of with glass. A part of the terrace was incorporated into the living space. These two measures meant that the concrete beams did not reach the outside anymore. For all exterior walls a new curtain wall system with 14 cm insulation and fibre cement elements was installed. The roof is the same as for the community hall while the windows have triple instead of double low-E glazing as in the community hall. Due to space constraints 2 cm thick vacuum insulation panels were laid in the classrooms and the activity room (see Figure 22).

For the rectory the external layer of concrete and insulation was replaced by a curtain wall system with 3 cm vacuum insulation panels and fibre cement elements (see Figures 23 – 25). The external wall of the stairwell was covered with a 8 cm composite heat insulation system. In the lower level walls between heated zones and non-heated zones were insulated with 6 cm insulation on the cold side. The windows and the roof were insulated as in the kindergarten.
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Figure 12. Lower level community hall

Figure 13. Upper level community hall

Figure 14. Cross section community hall
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Figure 15. Lower level kindergarten

Figure 16. Upper level kindergarten
Case studies overview

Figure 17. Cross section kindergarten

Figure 18. Lower level rectory
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Figure 19. Middle level rectory

Figure 20. Upper level rectory
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Figure 21. Cross section rectory

Figure 22. Kindergarten floor cross section with vacuum insulation panel

Figure 23. Rectory cross section with vacuum insulation panel
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Figure 24. Pre packing of vacuum insulation panel in polystyrene

Figure 25. Installation of pre packed vacuum insulation panel
6.3 Heating Ventilation and Lighting Systems

In the community hall the delivery station in the installation room was adapted and rebuilt to include a heat exchanger between the house installations and the district heating installations (see Figure 26). All pumps were replaced with differential pressure controlled pumps. The room temperature control system was connected to window contacts so that when windows are opened the room heating switches off. The radiators along the south facade were replaced. The ventilation system was removed. All lighting was replaced with low energy lighting. The electric installations were updated. Photovoltaic collectors were installed on the roof and the south facade.

In the kindergarten all pumps were replaced and room temperature controls were added as described above. The insulation on the connecting hot water pipes between the community hall and kindergarten was replaced. Solar collectors were installed on the roof to heat the DHW (see Figure 27). A supply and exhaust ventilation system with heat exchanger controlled by room VOC gas detectors was installed. Lights and electric installations were handled as described above.

For the rectory the heating circuit was adapted and replaced as required. Radiators were replaced on the south facade. Pumps and room temperature are controlled as above. Installation piping between community hall and kindergarten had the insulation replaced and improved. Solar collectors were installed on the roof to support the DHW heating (see Figure 28). An exhaust and supply ventilation system like in the kindergarten was installed. The lighting and electric installations were also handled as described above.

![Figure 26. Heating scheme community hall](image-url)
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Figure 27. Heating scheme kindergarten

Figure 28. Heating scheme rectory
7. Resulting Energy Savings

Two heating periods 2006 – 2007 were measured. The values used in this paragraph are the average from the two years and have been climate corrected (HDD for site/measured HDD*Energy consumption). The period 01.03.2003 – 29.02.2004 before the renovations took place is used as a comparison (see Figure 29). The apartment in the community hall had an increase heating energy consumption from 24% while the church showed a slight decrease of 2% from before the renovation. This is while neither was renovated. The kindergarten had a saving of 48% while the saving in the rectory was of a similar magnitude at 53%. The largest saving was in the community hall were there was a 73% reduction in heating demand. When comparing the total primary energy for all energy consumers for all three renovated buildings there is a reduction of 43%.

![Figure 29. Heating energy use climate corrected](image)

In the community hall (without apartment) the electricity consumption rose from 15.4 kWh/m²a measured before the renovations to 30.4 kWh/m²a in 2006 and 25.3 kWh/m²a in 2007. This is despite the low energy lighting. Investigations into why resulted in several possible causes. The activity rooms have a significant increase in usage since the renovations. The visualization and data logging systems for both years account for 3.4 kWh/m²a (see Figure 30). Unknown at the time was that two garages (one of which is a separate building but connected to the community hall’s electricity net) were heated with electric radiators and no one could say whether they where heated during the earlier period measured before the renovations. In the kindergarten (without apartments) the electricity consumption also significantly increased from 15.3 kWh/m²a measured before the renovations to 22.6 kWh/m²a in 2006 and 22.1 kWh/m²a in 2007. The explanation was in this case clear to see. The new ventilation system that was new accounted for 7.9 kWh/m²a in 2006 and 7.6 kWh/m²a in 2007 (see Figure 31). When deducted from the total consumption a small reduction in the rest electricity can be seen. In the rectory over a 100% increase in electrical power consumption was measured. Before renovations 9.4 kWh/m²a was measured, 19.9 kWh/m²a in 2006 and 25.0 kWh/m²a in 2007 were measured. The difference between 2006 and 2007 is because the apartment was empty for the first half of 2006 (see Figure 32). The difference between before and after was also investigated. One cause was the ventilation system that was not there before the renovations which accounted for 4.5 kWh/m²a. Another reason was the increased use of the offices and office aids e.g. computers, printers.
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Figure 30. Electricity use of the community hall (not including apartment)

Figure 31. Electricity use of the kindergarten (not including apartment)
On the roof and southern facade of the community hall photo voltaic collectors were installed extra to existing PV collectors (8.6 m²) on free standing masts. The PV collectors had energy gains of 21490 Wh/a in 2006 and 23481 kWh/a in 2007. This meant a reduction of the primary energy of 36.7 kWh/m²a in 2006 and 40.1 kWh/m²a in 2007 (see Figures 33 – 34).

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**Figure 32. Electricity use of the rectory**

**Figure 33. Primary energy before and after retrofitting (E. = Electricity)**
8. **User Evaluation**

There was no official user evaluation carried out. From the occupants there was nil feedback as to the retrofitting of the apartments. During the day when institute personal where visiting there was normally no one home. During visits for maintenance and control of the data logging system general discussions where held with the kindergarten teachers. The only area of dissatisfaction tended to be connected to the initial teething troubles with automatic systems for example jalousies opening when the sun shined or radiators switching of in the foyer when windows were used for airing in the WC. The air quality was deemed as good In Figure 35 can be seen that measured levels of CO2 and VOC levels were well under set health limits. Problems that the caretaker had included insufficient information on how to set the single room heating control, no information on the ventilation systems for example changing filters or where to obtain new filters and that there were no protection shields for radiator valves in the community hall as they were constantly being damaged. He also often switched the visualization computer and data logger off to save power not realizing that energy impulse counters were also switched off (separate system from that of the research project’s sampling system). The office workers where generally happy but found first thing in the morning that the air was not so fresh despite ventilation fan being 24 h in service so they would open the windows as first activity of the day even in winter.
9. Renovation Cost

The costs per net floor area cost group (CG) 300 (buildings – construction) and cost group 400 (buildings – installations) in the community hall are 574 €/m², the kindergarten 982 €/m² and the rectory 908 €/m² (see Figure 36). The costs for the PV modules are not included. The vacuum insulation panels are with 80 €/m² 3 – 5 times more expensive as polystyrene insulation with a similar U-value.
10. Experiences / Lessons Learned

One of the main lessons from this project was that careful planning is a must. It requires from the participants a commitment way above normal renovation projects. Those who try to complete this type of project in a time period as per a normal renovation project come under severe time pressure. Sufficient time must be allowed to enable careful planning to be properly carried out. Starting the project early enough meant data for a complete year before the renovations started could be collected. By comparing the measured energy consumption with computer simulated values at this stage showed that the actual energy consumption was significantly less than the simulated consumption. During the construction phase there was an employee change at the building planer as well as at the installations planner which caused some delays to the project but which fortunately could be made good. How well these situations can be bridged depends on the quality of the documentation.

The laying of the vacuum panels on the floor in the kindergarten presented no problems. However by the rectory the walls first had to be plastered to achieve an even surface. Not measuring the walls surface areas accurately resulted in openings between 1–2 cm between the panels which had to be sealed with polyurethane foam. In the rectory the ventilation ducting had to be hidden under a suspended ceiling which meant just enough height to walk around.

During the first winter the single room temperature control units were not used, because the community centre employees were not given any proper oral instructions or self explanatory manuals on how to operate the system. The system was not self explanatory. The DHW installations in the kindergarten showed significant circulation (continuous) and transmission losses. These losses were reduced somewhat by installing a time switch. In the rectory the circulation and transmission losses were higher than the actual consumption. With only one person living in the house the solar collector and circulation installations proved financially unviable.
11. General Data

11.1 Address of Project
Haslacher Weg 30, 89075 Ulm-Böfingen, Germany

11.2 Final Report / Revision No.
23. September 2009

12. Acknowledgements

Project Coordination: Günther Hermann Architects Stuttgart
Building Physics: Company for Building Physics Object Planning (GFO) Krefeld
Monitoring: Fraunhofer Institute of Building Physics (IBP) Stuttgart
Monitoring: Bavarian Centre for Applied Energy Research (ZAE) Würzburg
Heating Technology: T.P.I. Trippe + Partner Engineering Karlsruhe
National Support Program: German Ministry of Economy and Technology, Projektträger Jülich (PTJ)
Case Study Authors: Johann Reiss, Fraunhofer Institute of Building Physics (IBP)
Michael Beckert, Fraunhofer Institute of Building Physics (IBP)

13. References

[1] Diözese Rottenburg-Stuttgart; Kirchengemeinde „Guter Hirte“, Ulm-Böfingen; Solarstiftung Ulm/Neu-Ulm (Hg.): Realisierungswettbewerb Gemeindezentrum „Guter Hirte“ Ulm-Böfingen. Ökologische Bestandsentwicklung. Februar 2002