Results from the retrofit of seven multi-family units to the Passive House Standard

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1 Introduction

From 2008 to 2011, ABG Frankfurt Holding worked with faktor10, bauart Konstruktions, and Baumgartner to modernize seven multi-family dwellings built in 1956 with a total of 61 residential units (Figure 1). After modernization, the treated floor area was 3,850 m². After the work had been completed, all three building sections together (one block per building section) fulfilled the Passive House Standard, with one block slightly falling short of the requirements for new buildings at 17.5 kWh/(m²a) because of its east/west orientation. In addition to certified Passive House components readily available on the market, newly developed insulation façades made of renewable raw materials were also used. Heat was mainly to come from a cogeneration unit fired with rapeseed oil and three solar thermal arrays. Furthermore, comprehensive steps were taken to reduce distribution losses and energy demand for hot water supply. After tenants moved into the buildings, measurements were taken of consumption from spring 2010 to April 2013. In March 2012, a survey was taken of tenants to determine their satisfaction with the building and the building services, usage of the equipment, and the new calculation of rent including utilities.

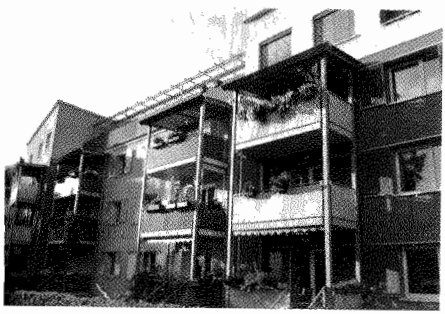

Figure 1 a & b: External views of the buildings after retrofit

2 Results of quality assurance measurements

The tenants all required comfort levels / room temperatures above the standard boundary conditions at 20 degrees Celsius used for planning. On the average, room temperature during the main heating months (January, February, March, November, and December) of 2011 was 22.2 degrees Celsius. Much higher room temperatures have also been found in

other high-quality energy retrofit projects for multi-family dwellings (Figure 2, measurement data in Rotlintstrasse are circles). The data reveal, however, that the apartments in Rotlintstrasse are at the top of the distribution shown. There are also differences in room temperature between the construction segments.

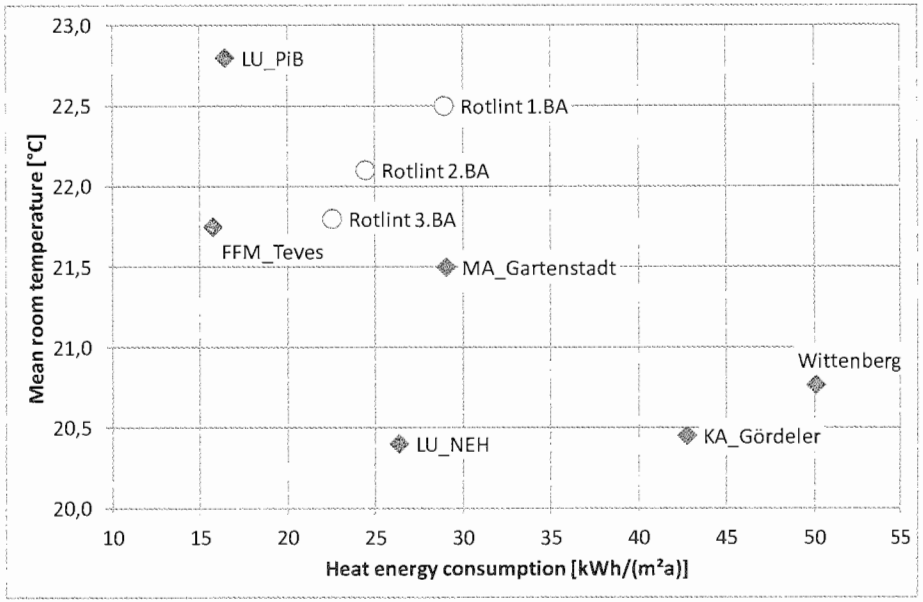

Figure 2: Mean room temperature at Rotlintstrasse 116-128 and other retrofitted apartment dwellings

The value for heat consumption measured in the apartments (Figure 3) was found to be 26.7 kWh/(m²a) (with slight variations from one block to another), thereby exceeding the demand projection calculated during planning of 15.2 kWh/(m²a). If the actual indoor room temperatures are taken into account along with the lower indoor heat sources (occupancy of 40.5 m²/person) determined during the survey, heat demand for the second (least favourable) block was found to be 24.6 kWh/(m²a) – compared to measured consumption in 2012 of 27.8 kWh/(m²a). The additional consumption in the buildings is therefore mainly the result of the tenants' greater comfort requirements and lower occupancy rates. Nonetheless, additional factors were found to influence the outcome:

- Greater indoor temperatures in the apartments (which users directly influence)
- Summer bypass for ventilation systems is not switched off for winter operation (heat recovery) quickly enough during maintenance (sometimes not until January!) (users have no influence)
- In some cases, summer mode for heating system when heating controls are manually operated (users have no direct influence)

- In some cases, use of shutters during the day in the winter (reduction of solar gains) (users have direct influence)
- Greater window ventilation in bathrooms during the winter in some apartments (directly caused by users)
- Smaller internal heat sources (users have only some influence)

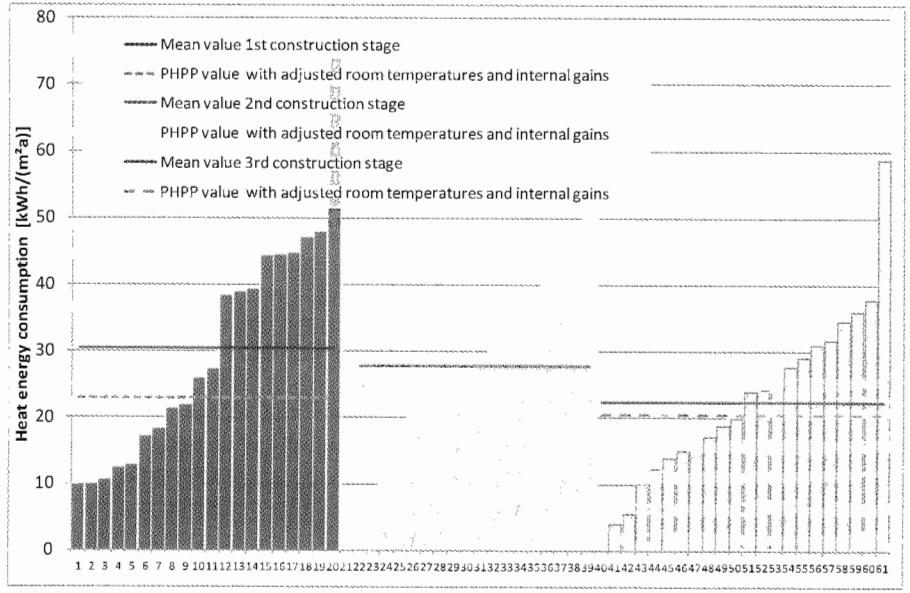

Figure 3: Measured heat energy consumption in 2012

In other words, the consumption levels measured are the combined result of technical causes and user behaviour. The gap between the design temperature of 20 degrees Celsius and the actual temperature range of 21.5 to 22 degrees Celsius in retrofitted rental apartments should be taken into better consideration during the planning of and calculations for zero and plus-energy buildings so that ambitious targets for the final and primary energy balances can be reached.

In 2012, the specific household power consumption was 25.2 kWh/(m²a). The planning value in accordance with PHPP was 28.2 kWh/(m²a), 11 % higher than the actual figure, while other measurements have found 30-33 kWh/(m²a) [such as Peper 2009]. Clearly, a considerable amount of energy can be conserved if consistent efficiency measures are taken, especially in the sensitive area of domestic electricity.

2.1 Operation of building services

The building services equipment includes a cogeneration unit, a gas condensing boiler, three solar thermal arrays and a district heat network with three semi-central plants. It is complex system and a number of bugs had to be worked out. In two of the three blocks, the solar pump failed shortly after being put into operation, bringing the share of solar heat down to zero until the problem could be resolved. If these problems had not been monitored constantly for scientific research, they would probably not have been discovered for quite some time. In the second block, which worked properly, the share of solar heat reached 55 % in 2011. Monitoring also allowed points to be detected where return flow flaps were not working well or had not been installed – and were therefore preventing parts of the system from operating correctly, such as the interplay between the cogeneration unit and the gas condensing boiler. Efficiency could also be increased further by optimizing operation, for instance by switching off circulation pumps. The cogeneration unit fired with rapeseed oil ran reliably for the first few months before it had to be temporarily switched off because smoke started building up and noise became an issue in an apartment on the top floor in May 2011. The specialist planners and the manufacturer of the cogen unit then joined forces with other experts to reduce noise from the cogen unit's exhaust gas lines; in addition, a special soot filter from a fork lift truck was installed, allowing the unit to go back into operation in December 2012.

Experience from system operation and monitoring reveals that equipment for providing buildings with renewable energy often still has bugs – especially when used in city centers and in multi-family complexes; sometimes, there is simply a lack of affordable monitoring functions to detect and fix problems quickly. Systems should be monitored at least for the first two years, especially if the system is particularly complex, to ensure it is working properly. Unfortunately, there are no low-cost solutions, and components from different manufacturers often do not communicate well with each other. Nonetheless, consumption of heating energy on Rotlintstrasse was low – an indication of how important efficiency increases in the building envelope are; the priority should be on efficiency before the use of renewables or the budgeting of credits is taken into consideration.

3 Assessment of rent+heat model

In accordance with the exceptions for Passive House made in Section 11 para 1 no. 1a of the German Heating Cost Ordinance (HeizV), heating expenses are not individually charged by apartment; instead, a flat rate is applied for rent and heating expenses. In addition to the cost of space heating, heat for hot water is also part of the flat rate (but the volume of hot water was not), as hot water mainly comes from solar energy and cogeneration (Section 11, para 2 HeizV). Originally, HeizV was adopted to provide incentives for people to reduce their individual consumption along with the switch from flat rate invoices to invoices based on household consumption. Now, the question is whether the switch back to flat rate invoicing and the resulting lack of an incentive will lead tenants to consume more. The indicators used for this investigation were measurements of heating

energy consumption within the apartments, individual room temperatures, and water consumption, each of which was expressed in per capita terms or by floor space.

Measurements did reveal significantly greater heating energy consumption, but that was mainly a result of the room temperatures measured and the delay in switching the ventilation system from summer to winter operation. Room temperatures were only slightly higher than those found in other Passive House projects with separate heating bills (Figure 2), so the rent+heat model does not seem to have had a great effect. It is possible, however, that room temperatures would have been slightly lower had heating costs been separately invoiced. At a later date, tenants were informed about how to use technology in their apartments correctly and about optimal ventilation and shading. In 2012, per-person hot water consumption came in at 48.4 l/(p*d), far above the expected level (25 l/(p*d)), probably because of the rent+heat model. Tenants have no incentive to use cold water, such as when washing their hands or cleaning vegetables. The assessment of the rent+heat model is therefore mixed. Heat consumption is slightly higher, but still seems to be reasonable. But when no distinction is made between hot and cold water on bills, measurements in Rotlintstrasse show that far more hot water is used, thereby increasing energy consumption. The effects are undesirable even if renewable energy is used.

4 How tenants view the rent+heat model

In addition to review measurements, tenants were asked to assess the rent+heat model as part of a comprehensive survey. While 55 % of those surveyed approved of it, 35 % would have preferred heating bills by building or household. Low and high-income households approved of the rent+heat model more than middle-income households did. Regardless of personal preferences, most tenants found the rent+heat model to be good to very good (87 %), sensible (77 %), and modern (80 %), though the model was generally found to be strange and less just. Taking into account how long tenants had been in their apartments (between one and three heating seasons), it was found that familiarity with the billing model increases over the years, though acceptance slightly decreases. When asked what benefits the model provides, the main answers given were planning certainty for tenants and lower costs for equipment and staff. The drawbacks mentioned include having to pay for others and having to trust others to conserve. Answers to the question of whether the rent+heat model influenced people's decision to rent were also interesting. For instance, 54 % of those who support the billing model said it was definitely or possibly one reason. But 44 % of those who do not prefer this billing model also said it was a reason why they signed the contract. The billing model was an important reason to pick the apartment for 35 % of all tenants across all income groups. If we include the "maybe" answers, the greatest support (80 %) was among low-income households, with middle and high incomes ranging from 47 to 64 %. After location (proximity to downtown area) and balcony/terrace, the amount for total rent was the third most important criterion in choosing an apartment here.

5 Conclusion

This retrofit, which mainly used renewable insulation materials, reduced energy consumption for space heating and hot water by 70 % based on measurements taken before and after. Domestic power consumption fortunately came in around eleven % below what was expected. The system technology used in the project showed that systems that provide renewable energy to multi-family complexes still need to be made much more reliable. In addition, operation has to be optimized for all of the savings potential to be tapped. Most of the tenants very much approved of the billing model, which was a reason to choose this apartment for a number of them. Heating energy consumption only increased slightly, so the rent+heat model can also be taken as a marketing opportunity for the housing sector. However, this billing model seems questionable for hot water expenses based on this project.

6 Acknowledgments and references

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