

## PASSIVE HOUSING – A SUSTAINABLE ANSWER TO MAINSTREAM USER NEEDS?

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### Abstract

Passive housing (PH), a sustainable building model with high-grade insulation, passive solar gain and ventilation with heat recovery, has entered the social housing mainstream in Central Europe. Political regulations are likely to make low-energy housing mandatory, so it has to be asked whether the PH solution satisfies conventional needs to succeed on the housing mass market. First answers are provided by an Austrian post-occupancy evaluation (POE) project comparing nine new passive housing estates (344 evaluated housing units) with 244 conventional ones. In PH, air quality and ventilation move into the focus of users. POEs detected three weak points of PH in the eyes of lay people: the adaptation phase of ventilation/heating, dry air in winter and possible overheating in summer. Instrumented POEs in Salzburg on PH air quality showed that the behavior of users moderates/worsens the system status. As energy saving is no primary housing motif of residents, the success of PH will depend on the quality of technical solutions, intelligent communication and service.

### Streszczenie

Pasywne budownictwo (PH), jako zrównoważony model budynku z wysoko klasyfikowaną izolacją, pasywnym zyskiem słonecznym i wentylacją z odzyskiem ciepła, wszedł w społeczny główny nurt domów w Europie środkowej. Regulacje polityczne mogą sprawić, że uwzględnienie zasad budowy niskoenergetycznych domów stanie się obowiązkowe, powstaje więc potrzeba sprawdzenia czy rozwiązanie PH zaspokaja potrzeby konwencjonalnego użytkownika, by odnieść sukces na rynku domów. Pierwsze odpowiedzi są dostarczone przez Austriaków w ocenie POE (post-occupancy evaluation), w porównywaniu dziewięciu nowych pasywnych domów (344 ocenionych części domów) z 244 konwencjonalnymi. W domach pasywnych, jakość powietrza i wentylacja skupiły uwagę użytkowników. Badanie POE wykazało trzy słabe punkty PH w oczach ankietowanych ludzi: faza adaptacji do wentylacji / ogrzewania, suche powietrze w zimie i możliwe przegrzewanie w lecie. Badanie POE domów pasywnych w Salzburgu na jakość powietrza pokazało, że użytkownicy odnoszą się w sposób zachowawczy lub niezadowolający do systemu. Oszczędność energii nie jest najważniejszym atrybutem dla mieszkańców domów pasywnych, sukces PH będzie zależał od jakości technicznych rozwiązań, inteligentnej komunikacji i obsługi.

Keywords: Passive housing; Post-occupancy evaluation; Technology mediation; Social design; Ventilation; Overheating; Air quality.

## 1. INTRODUCTION

The housing evaluation methods of *user needs analysis* (before planning) and *post-occupancy evaluation* (POE; after construction) are 30 years old and were mainly used in the Angloamerican world [1; 2]. For the

successful implementation of sustainable buildings, the social acceptance of new technologies like passive housing (PH) will be one of the key factors.

## 2. PASSIVE HOUSING FOR THE MAIN-STREAM

### 2.1. Coming of age of an experimental concept

Room heating makes up over 50% of the energy costs for an average household. Feist et al. developed the European passive house (Passivhaus, PH) standard of sustainable building quality [3]. By a combination of optimum wall, roof and window insulation, solar building orientation and a ventilation system with heat recovery via heat exchange, it realized an energy demand level of 15 kWh/sqm/year and lower. Feist discovered the behavior of the users as a moderator variable [4]. At the low demand level around 15 kWh/sqm/year – compared to over 100 in conventional housing – the performance of the users (heating, ventilation behavior) modifies PH energy efficiency to a lesser extent.

The first German Passive House of 1991 at Darmstadt-Kranichstein, Hessa, successfully passed a POE [5]. Further German PH POEs were done, mostly at Hessa. In 2000, the Austrian research focus “Building of Tomorrow” supported a first comparative POE about sustainable and conventional housing projects in Salzburg City [6].

### 2.2. POE of nine passive versus conventional housing estates

For the building industry and politics, low-energy mass housing is a chance to cut costs and to meet climate standards, but also a risk to lose credibility and money in case of bad technology and lack of social acceptance. Therefore, Austrian POE gained importance when passive housing entered the mass market. After a test phase with detached PH, the first multi-storey PH properties at Vienna (Muehlweg, Utendorfgasse, Roschegasse, Dreherstrasse, Kammelweg B & E) and Salzburg (Samer Moesl, Franz Ofner Strasse, Paradiesgarten) with 694 housing units were occupied between 2006 and 2009.

*PH Vienna-Muehlweg* (Fig.1a): In northern Vienna, architects Dietrich and Untertrifaller planned a wooden structure of five floors occupied in late 2006. POE-1 was in spring 2007, POE-2 in spring 2010.

*PH Vienna-Utendorfgasse* (Fig.1b): Near the Western railroad line, architects Schoeberl and partners planned a concrete structure of five floors, occupied in late 2006. POE-1 was in spring 2007, POE-2 in fall 2008.



Figure 1 a-c.  
Vienna PH Muehlweg (a), Utendorfgasse (b), Roschegasse (c)  
(photos: author)

*PH Vienna-Roschegasse* (Fig.1c): In the southeast, architects Treberspurg and partners planned a concrete, five-floor-structure. The city block structure with two yards opened in late 2006. A POE followed in spring 2007.



Figure 1 d-f.  
Vienna PH Kammelweg B (d), Kammelweg E (e),  
Dreherstrasse (f) (photos: author)

*PH Vienna-Kammelweg-B and -E* (Fig.1d-e): In northern Vienna, architects Schindler & Szedenik (B) and Kaufmann (E) planned two concrete structures of seven floors, occupied in late 2007. POE came seven months later.

*PH Vienna-Dreherstrasse* (Fig.1f): In the southeast of Vienna, architect Lautner planned an estate of five roundish concrete structures, one of them a PH of



Figure 1 g-i.  
Sbg.PH Samer Moesl (g), F.Ofner Str.(h), LEH/PH  
Paradiesgarten (i) (photos: author)

five floors. It opened in fall 2007. BUWOG did an internal POE after seven months and a second one in fall 2009.

*PH Salzburg-Samer Moesl* (Fig. 1g): In northern Salzburg City, architect Speigner planned a wooden structure of three floors. The three building rows opened in fall 2006. A POE was done in spring 2008.



*PH Franz-Ofner-Strasse* (Fig. 1h): In the northwest of Salzburg City, architects Mayer and Seidl planned a concrete structure of six floors, occupied in late 2007, evaluated in late 2008.

*LEH/PH Paradiesgarten* (Fig. 1i): South of the Salzburg City center, architect Kofler planned a five-floor housing group of several low-energy buildings (owner-occupied) and several PH buildings (rented), occupied in late 2009, evaluated in spring 2010 (sample of 20 apartments) [7], re-evaluated in summer 2011 [8].

Most Austrian multistorey PH objects had similar heating model computation results and favorable blower door building density records (see [www.igpassivhaus.at](http://www.igpassivhaus.at)). Six PH properties have central ventilation systems, decentralized ventilation is used at three. The air temperature regulation uses heat recovery systems with heat exchangers in nine cases. For technical details see [www.hausderzukunft.at/english.htm](http://www.hausderzukunft.at/english.htm).

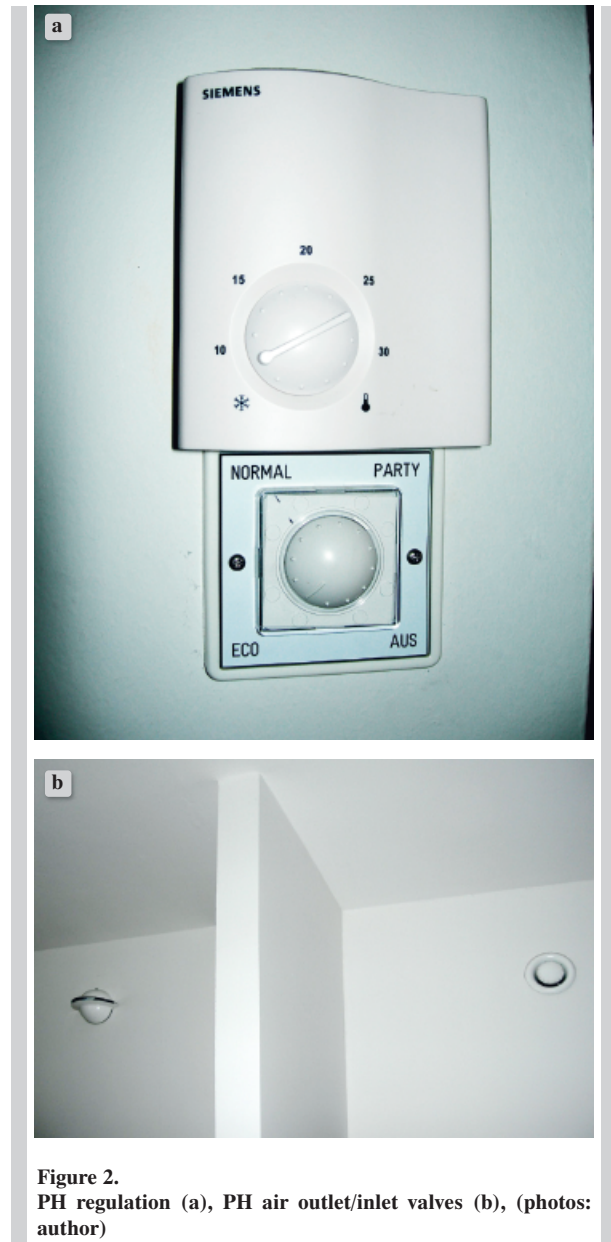
### 2.3. Diffusion of innovations – lessons to be learned

PH technology is at first sight unusual, not self-explanatory. European dwellers know wall sockets, light switches, wall or radiator thermostats, but not a central heating and ventilation regulation (see Fig. 2a) with air inlet and outlet valves outside bathrooms (see Fig. 2b, both from PH Utendorfsgasse).

New occupants need information on the PH system configuration for optimum user behavior. Therefore, PH technology is a case for lay theories [10], mental models [11], and the diffusion of innovations [12]: To be successful, a PH should not be too complex, should enable trials and observations by the users. POE is a tool to find supporting or obstructing factors for PH market introduction [13].

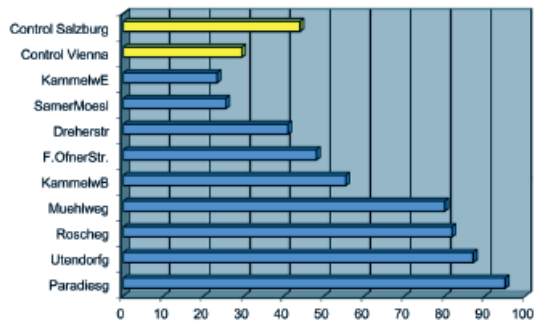
Our standard PH POE method was a two-page questionnaire. It had between 35 and 44 items – 5-8 sociodemographic items, 11-18 qualitative and 18-24 quantitative questions. A 19-items core remained constant for the nine projects, other items were project-specific. PH Dreherstrasse was evaluated by an internal 28-item instrument of the BUWOG company. Of 694 new PH units, 344 were evaluated (49.6%) [14]. A control group of 244 conventional housing units was tested in 2008 and 2009 – 156 were Vienna buildings, 88 from Salzburg City.

Between 40 and 80% of our PH questionnaires were returned. They were filled in by 40 to 70% females. The mean resident age was between 34.5 and 41.3, the age range between 19 and 82 years. The mean



household size was between 2.1 and 3.1 29-65% were two person-households, 25-83% were households without children. Mean apartment sizes ranged between 73 and 94 square meters.

Mean housing satisfaction (measured in a five-point Likert scale) was between 1.0 and 2.1 – 23-100% used the category “very satisfied”. Kammelmweg-E (23.3%) and Samer Moesl (25.5%) were lowest, Paradiesgarten highest. Fig. 3 shows a comparison of all estates. Four properties are in the high-satisfaction category, followed by two above mentioned control levels. One is at the control level, two are even lower.



**Figure 3.**  
POE percentages of “very high housing satisfaction”, PH (blue) and controls (yellow)

The question “Do you know characteristics of a PH?” was answered with “yes” by 35% to 94%. In six of the nine properties, self-reported PH information was over 70%. A control question about the amount of heating costs saved in PH (none, under 50%, over 50%) was correctly answered by 45-50% in two projects with communication and motivation problems, but up to 85-92% by well-informed PH residents.

Personal sympathy is a central feature of successful brands [15]. Asked about sympathy for PH, two properties ranked low (30-39%). Five estates had sympathy values between 64 and 84%. Utendorfgasse residents self-reported 84% sympathy in POE-1, and 93% in POE-2 the next year. Thus, PH established brand quality in some properties (Muehlweg, Utendorfgasse, Roschegasse, Dreherstrasse), but failed to do so in others (Kammelweg-E, Samer Moesl).

PH is advertised as sustainable, energy saving housing. Whereas energy saving in general shows a high social support in European surveys, it is still an open question whether it makes innovative housing attractive and promotes the diffusion of innovations [12]. The POEs asked whether PH was the “first choice feature” for residents or whether other features (e.g. location) came first. There were medium PH choice values (40-53%) for three properties. Kammelweg-B (24%) and especially Utendorfgasse (7%) signalled low PH choice importance. Two Salzburg estates were “filled” by the local housing department.

In all properties evaluated, no gender effect was present with regard to housing satisfaction, PH knowledge, PH sympathy or energy saving. Muehlweg showed a significant age effect for PH knowledge by young people, Franz-Ofner-Strasse another one – older residents expressed more sympathy.

## 2.4. Strong and weak points of passive housing in lay perspective

Summing up results of the Austrian PH POE series, dwellers expressed mostly high housing satisfaction, also about the energetic performance of the innovative building type, even if it had been no primary choice criterion for their housing decision. But PH satisfaction needs communication – when residents did not negotiate their housing type and/or when problems were not properly handled, the resulting satisfaction was only average, near conventional housing. Also, three weak points of PH in lay perspective emerged in the POE series:

1. Heating an apartment via ventilation is an unusual concept for residents and they have to be briefed about a necessary adjustment period of the system. 12% to 58% heating regulation problems and defects were reported just after the residents had moved in. At Kammelweg-E, severe complaints led to measurements and a system improvement. Optimum PH system performance in summer and winter also needs communication with the residents.
2. Winter PH problems had to do with temperature regulation and with dry air. Heating up cold inflow air with warm outflow air via a heat exchanger automatically produces dry warm air, as the cold outside air contains low amounts of humidity, and warming makes it even dryer. This is true for PH heat exchange, but also for conventional room heating. As complaints about dry air were expressed by up to 24% of PH dwellers, but also by up to 19% of control group residents in conventional housing, dry air is a general feature of housing in winter and not a PH result.
3. In some PH properties, overheating of the apartments in summer was criticized. PH insulation and ventilation make up a rather inert system, so it is necessary to keep apartments cool by shading and, if necessary, nighttime window ventilation, as PH ventilation alone cannot lower room temperatures as fast as air-conditioning.

Different planners and companies had different information concepts – mostly a mix of written material, resident meetings and on-site explanations. Overall, six properties showed (above-) average information, three were suboptimal. Two of the latter were the properties with low housing satisfaction. Information is not the only factor, but important for the PH image.

A PH lay theory event was recorded at Muehlweg

after move-in. A rumour spread that the house would freeze when people went on Christmas vacations, “because PH is only heated by its residents”. The BAI company countered that the PH insulation has a slow cool-off time function, and that small radiators were installed in every apartment.

### 2.5. Instrumented POEs of winter and summer air conditions

To gain further insights into complaint areas 2 and 3 – dry winter air and summer overheating – two instrumented POEs were run in Salzburg City in 2009/10 and 2011 with the support of Wienerberger AG [7,8,9]. The winter POE studied 20 housing units of Paradiesgarten, partly low-energy estate, partly PH, with resident diaries and two thermo-hygro-dataloggers per apartment over four weeks. In four flats, carbon dioxide measurements were taken. It was found that subjective air temperature was good in 79-84% of the diary dates, subjective humidity in 73-85%, and subjective air quality in 73%. Subjective air quality and humidity correlated significantly. I.e. dry air was linked with bad air quality whereas – according to measurements – carbon dioxide values rose with higher humidity. The low-energy apartments had only exhaust air ventilation and 58% of the dwellers opened windows for additional ventilation. The PH part had full ventilation, and only 25% of its inhabitants opened windows.

The summer POE studied ten apartments of the Salzburg City PH properties Paradiesgarten (5-floor, brick&concrete), Postareal (8-floor, concrete), and Samer Moesl (3-floor, wood), in August 2011. Participants kept diaries on satisfaction with temperature, humidity, air quality, and their shading and ventilation behavior. Two thermo-hygro-dataloggers were used per apartment and additional carbon-dioxide measurements taken in the three estates. Logger living room temperatures correlated significantly with the number of persons present, with subjective air quality, and – in two estates – with subjective temperature wishes. Logger living room humidity did not correlate with subjective humidity wishes. Only at Paradiesgarten, measured living room air temperatures correlated significantly with shading behavior. Effective self-reported ventilation behavior (windows closed at daytime, opened in cooler nighttime) correlated with living room air temperatures in all three estates. Problems with high living room temperatures were caused by open bottom-hinged sash windows at Paradiesgarten estate and by open balcony doors at Postareal estate. Of 295 diary episodes, 69% record-

ed effective and 31% ineffective user summer ventilation. Thus, PH occupants should be instructed better how to shade and ventilate apartments in hot summer periods to optimize the performance of the PH and to reduce complaints.

### 2.6. Outlook

What Sommer already called “social design” in early POE years [16] should be realized in innovative housing – PH should become a learning system. POE is a powerful tool to probe the social dimension of this innovation process, and can also help to identify main needs of the users for the next design cycle in sustainable buildings. As energy saving is no primary housing motif of lay people, the success of PH will depend on the quality of technical solutions, intelligent communication and service.

In Austria PH spreads exponentially – properties of over 300 housing units have opened, in Vienna a PH complex of over 700 units is just being occupied. More POE will be necessary to secure quality standards. Visionary EC programs announce zero and plus energy buildings next – but what about their social sustainability? With rising housing standards in eastern countries, PH solutions will move in and should be quality checked. An English version of our POE instrument is available for comparison studies of foreign housing properties.

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