Post-Occupancy Evaluation by the test families in five Model Home 2020 across Europe

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Abstract: *This paper describe the Post-Occupancy Evaluation (POE) of five families living, for one year, in the Model Home 2020. The houses are located in Germany, Austria, France and UK. The survey is carried out seasonally during the test year the family lives in the house allowing to capture and explore variation on a seasonal basis. The questionnaire is focusing on energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability. The results give an indication of what the families think of the houses, of its interior environment, and how the environment is experienced etc. In general, the families indicate high satisfaction with the indoor environment, better health, fewer sick days and improved sleep quality, that their expectations often are fulfilled, that house automation is acceptable, and being able to follow energy consumption and production increase awareness of their behavioural influence.*

Keywords: Model Home 2020, Post-Occupancy Evaluation, Interior Environment, Sustainability, Health and Sleep Quality Lorem, ipsum

Introduction

Through 2008-2012, six demonstration buildings are designed and constructed; one is a new-built office building, one renovation of a single-family house and four new-built single-family houses. The intent with the Model Home 2020 strategy is to combine excellent indoor environment with high quality homes mainly driven by renewable energy sources as contextually optimized design solutions [1-4]. Thereby, the houses are designed, built and constructed as state-of-the-art homes with the newest technological developments and high quality materials.

These houses are built to explore possibilities in future technical as well as perceived sustainability. All houses have automatic systems installed as to optimize indoor environmental conditions, for instance by automatically opening and closing windows to air out exhaust or warmed air, pull down solar shading to prevent too much solar gains or shut windows when raining. Sensors are installed in each house in each of the rooms to register indoor environment conditions (temperature, CO2 levels, relative humidity, lux) and regulate based on these values. A weather station is installed on the rooftop of the house to register outdoor weather conditions (temperature, rain, global illuminance, hours of sunshine and wind direction). These data are used to adjust the indoor environmental conditions to the comfort of the occupants. Four Model Homes 2020s houses LichtAktiv Haus (Germany) [1],

Sunlighthouse (Austria) [2], Maison Air et Lumiére (France) [3], and Carbon Lighthouse (UK) [4], and their occupants are subjects to this paper.

Model Home 2020

LichtAktiv Haus was built in 2010 and the family moved in December 2011. LichtAktiv Haus is the first CO2-neutral modernisation of a so-called Siedlerhaus, a semi-detached house from the 1950s located in the Wilhelmsburg district of Hamburg. The innovative modernisation strategy combines maximum liveability with optimum energy efficiency. The once tight and closed structure of the building has been transformed into spacious rooms with high levels of daylight, providing occupants with the best living comfort. Natural ventilation ensures a healthy indoor climate. The refurbished house contains of two children's rooms, two bathrooms, a master bedroom, a central living area and a reading room. All rooms feature façade and roof windows that are positioned to ensure optimum distribution of daylight. The floor area of the house is 185 m^2, and the glass area is equivalent to 58 % of the floor area. To provide electricity and hot water solar collectors and photovoltaic solar cells were used – everything to cover energy demands of the house.

Figure 1. Photo of the LichtAktiv Haus (Germany) to the left and Sunlighthouse (Austria) to the right (Photo by Adam Mørk).

Sunlighthouse was built in 2010 and the family moved in February 2011. Sunlighthouse is Austria's first carbon-neutral, single-family home. The vision is to build a house with exciting and appealing architecture focusing on the sloping roof. The house must be generally affordable and therefore meet certain specifications of dimensions, material and appearance. Sunlighthouse provides an exceptionally high proportion of daylight and will achieve a positive energy balance by reducing its overall energy consumption and by using renewable energy. The net floor area of the house is 201 m^2, and the glass area is equivalent to 36 % of the net floor area.

Maison Air et Lumière was built in 2011 and the family moved in September 2012. Maison Air et Lumière is a new generation of active homes that puts the quality of life of its

inhabitants at the centre of its environmental approach. The unique features of the house lie in intelligent use of the sloping roof to combine well-being and energy efficiency. The architectural concept is based on different roof pitches that increase its ability to capture sunlight, making it an energy-positive home. The pitched roof is part of France's cultural heritage. Roof pitches vary in steepness according to region and climate – and to meet the need for light and solar gain. Carefully positioned façade and roof windows bring in sunlight from all directions. The windows also fill the space with fresh air to ensure a comfortable living environment all year long. The 130 m² floor area extends over one and a half storeys, with the spaces under the roof put to full use, with a window-floor ratio nearly 1:3.

Figure 2. Photo of the Maison Air et Lumiére (France) to the left and the Carbon Lighthouse (UK) to the right (Photo by Adam Mørk).

CarbonLight Homes was built in 2011 and the families moved in January 2013 and April 2013. CarbonLight homes are the first new home in the UK designed and built to the new UK Government definition of zero carbon and will achieve level 4 of the Code for Sustainable Homes. They are designed to be real homes for real people with construction techniques suitable for use by mass house builders. CarbonLight Homes use nature in an intelligent way to maximise daylight and encourage a sustainable lifestyle. The design is open plan and incorporates high levels of daylight and natural ventilation intended to minimise energy consumption among residents and generate a sense of community. The homes show that common-sense design can be used to create inspirational sustainable houses that can be easily replicated by UK house builders. The net floor area of the houses is 230 m^2, and the glass area is equivalent to 24,5 % of the net floor area.

Post-occupancy Evaluation

In all ModelHomes 2020, a family will live in the house for a full year to help measure, monitor and assess what they think about each of the ModelHomes. The survey is carried out seasonally during the test year the family lives in the house allowing to capture and explore variation on a seasonal basis with approximately three months in-between. The intent with

four replies per house is twofold. Firstly, this is to identify if the occupants experience their perception changes during the stay; for instance – is their perception of indoor environment, expression, comfort or automation changing through their stay. The second aspect to the seasonal distribution is to explore if seasonal changes in weather, and thereby for instance dynamics temperatures, daylight, influence occupant experience. The outcome with the post occupancy evaluation (POE) of the houses is to get indications, from the families, how successful the Model Home 2020 are, and if challenges or problems, what can be learned and improved.

The questionnaire, translated into their native language, is mainly focusing on energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability [5]. It is a set of questions relating statements about satisfaction/dissatisfaction with the focus area described above, about frequency of occupant interaction with elements of the house, and if the house fulfil expectations of the occupants. In this study, the advantage of using questionnaire is that it is easier to distribute several times, but the disadvantage is the limited number of houses studied, and thereby statistical tools that can be used to draw significant conclusions from survey. Anyway, by employing these questionnaire four times during each family test year, we get indications of users' reactions to the house as well as gaining a better understanding of what is most important in the house environment to focus on

Results

The questionnaire is divided in the following subjects:

- Demographic questions (9 questions)
- Energy (5 questions)
- Indoor climate (15 questions)
- Control Units (7 questions)
- Electrical, natural light view (11 questions)
- Environment and sustainability (8 questions)

The questions about satisfaction were made as sets of Likert-scales categorised as *very satisfied, satisfied, neither satisfied nor unsatisfied, unsatisfied,* and *very unsatisfied*. Questions about how comfortable the subjects are in their indoor environments are categorised on a five-point rating scale by: *very rarely, rarely, occasionally, frequently, and very frequently*. Finally, the questions about energy, environment and sustainability were made as sets of statements and categorised as a three-point scale *yes, very, yes to some extent, no normally not*, or as sets of five-point scales *strongly agree - strongly disagree*, and *very good – very bad*.

The demographic questions about the family and their children (age between 0 and 9 years) show that most of the residents have a working week away from the house (one family member work from home a few days per week). When at home, they normally spend between 11 to 16 hours on weekday in the house, while longer time in the weekends (between 16 to 20 hours). When asked if they experience their health as better or worse compared to former home, there is a clear tendency that they feel their health is "better" (72%). They also experience that their sleep quality compared with former home is "better" (50%) or "almost the same" (39%), and when rating their children's sleep quality, the tendency is a bit higher ("better" 56%; "almost the same" 44%). Furthermore, they have a significant experience that they have "less" sick days (83%) than in their former home, and they state their general health all in all is "good" or "very good".

In general, the residents where, to some extent, conscious about their energy consumption, environmental impact on their daily behaviour, hot water consumption, electric lighting use, and media attention on global warming to their energy consumption. Interestingly, living in these houses for one year did not make the family members more conscious with these topics over time, rather reverse or indifferent. Most of the residents were aware, in their statements, that the PV panels and the solar thermal collectors do not produce the amount of energy needed for electricity and hot water, although there was a tendency of higher awareness of the hot water use at the end. Among the residents, there were slightly different response, but the tendency between the beginning and end of the year, show similarity. The residents felt good about knowing that the house produces much of its own energy requirement, and that climate changes had altered their behaviour, but they were more indifferent regarding spending on energy generating products. However, they liked the signalling value of the energy technologies used (PV panels and solar thermal collectors) and felt these technologies are well integrated in the design of the houses. They are generally "concerned" or "very concerned" about minding the environment as well as saving energy.

Generally, the indoor climate is rated as "very important" and the residents state most of the time that it is "good" or "very good" for the house in general and three rooms in focus (>90% state "good" or "very good"); the kitchen, the living room, and the bedroom. When the residents were asked to choose three conditions they would like to change to make the indoor climate more comfortable to live in, they reported less noise from the window opening systems, less peeping inside (privacy) and better electric lighting. Across all the houses, the residents are either "very satisfied" or "satisfied" with the temperature conditions in general (90%) and the three rooms in focus (>85% state "very satisfied" or "satisfied"). Most of the times, the temperature conditions is assessed as about right, but separated into the different season of the year, the winter and the spring/autumn is stated as time of the year when temperature is sometimes evaluate as varying, while few state temperature as too hot, even in the summer. The air quality is rated as "very acceptable" (78%) or "acceptable" (22%), and they state, in general, that they have not experience any problems at all. If they want to improve the air quality, they open the facade and roof windows, and make draught. The sound and acoustic conditions in the houses show more mixed evaluation. Generally, the satisfaction

level is lower for sound and acoustic conditions (56% “satisfied”; 33% “dissatisfied”) than the other indoor climate conditions, due to the fact that the residents are more bothered by the sound of the facade and roof windows, when they automatically opens.

About house control system to operate the indoor climate, the residents state that the control unit most frequently used is the screen, remote control second, while manually operating is the least used unit. They are generally “very satisfied” or “satisfied” (>85%) with the way the house system operate the facade and roof windows, the indoor temperature, internal and external screen, and ventilation system (one house is natural ventilated). They have a clear feeling that the way the control unit operate the house support their needs, and it “easy” or “very easy” to use. It shows further that they “rarely” or “occasionally” use the control system to manually operate the facade and roof windows, internal temperature, but more frequently use the control system to operate the screening. When operating, there is a clear preference to use the screen/remote control, and not too often, they do it manually.

Between 67 and 89 % of the resident reported that they were “satisfied” or “very satisfied” with the artificial lighting in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom. They state they turn the electric light on “less often” (100%) than in their former home, and they evaluate the light levels as “appropriate” (>72%) in the focus rooms .

The daylight levels in the house is rated either as “much higher” (88%) or as “higher” (12%) than their former home. They report that the daylight level is generally “appropriate” (>75%) in the kitchen, the living room, and the bedroom. There is a difference among the houses, where one house find there is “not enough daylight” in the kitchen, while another house evaluate the daylight level in the bedrooms as “too much daylight”. Between 89 and 100 % of the resident reported that they were “satisfied” or “very satisfied” with the daylight in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom. They also state the windows is “about right” for all the rooms (>89%). Their preference for sunlight in the kitchen and living room is generally in the morning, in the afternoon and in the evening, while in the bedroom there is a clear preference for sunlight only in the morning. This could be the reason that they feel sometimes bothered by sunlight in the bedroom, while this is not an issue in the kitchen and living room.

View to the outside through the window is rated as “very important” (44%) or as “quite important” (50%). Between 72 and 83 % of the resident reported that they were “satisfied” or “very satisfied” with the view in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom.

The residents state the location of the house on site is right and that the location in relation to daylight and sunlight is good. They do not find it too close to neighbours or roads. Their opinion if the house fit into the neighbourhood is “yes, very” or “yes, to some degree” (88%), and they have fairly clear opinion that house like this will be more common in the next 20 years. Their immediate impression of the house was futuristic, eco-consciousness and good

architecture, but they find it possible to make architecturally attractive houses with PV Panels and solar thermal collectors, as well as an example of an architecturally attractive house.

Conclusion

The conclusion of the POE indicate, in general, that the families show high satisfaction with the indoor environment, that their expectations often are fulfilled, that house automation is acceptable, and being able to follow energy consumption and production increase awareness of their behavioural influence. Furthermore, combining excellent indoor environment with high quality homes, like Model Home 2020, give clear indication that the residents experience better health and better sleep quality, as well as having less sick days than when living in their former homes.

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