Tomorrows buildings today – results, conclusions and learnings from a cross-european demonstration programme

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Abstract: *"One experiment is better than a thousand expert assumptions" forms the point of departure for a cross-European demonstration programme of 6 model houses. All projects base on the active house principles and were tested 1:1 and evaluated scientifically in post occupancy evaluations. The research feedback is expressed in a comparative benchmark model developed for the purpose of qualifying theory into practice and back into theory.*

The paper presents the main common denominators among the houses and identifies distinct learnings among the many findings through excerpts from the real-life monitoring in the form of quotes, and via the methodology developed as a result of the social monitoring. The scientific reports and conclusions are the body of the empirical studies, forming a platform for discussion, definition and suggestion of common denominators; finally concluding into a recommendation catalogue of conclusions for learnings transferred to the wider housing stock, new as well as existing

Comfort, Active House, Livability

Introduction to the demonstration project programme

During 2009-2011, a demonstration project programme of 6 model homes were built in Denmark (2009), Austria (2010), Germany (2010), France (2011) and United Kingdom (2011). All houses base on the Active House principles (Alliance, 2013), Comfort, Energy and Environment (fig.1). The buildings have been tested and monitored in use, under post occupancy evaluation schemes by national research teams of engineers and / or scientists.

The approach to optimise livability whilst minimising impact is in short the aim to adapt to current requirements of modern family living, interpreted into a healthier and more comfortable life for the occupants, without a negative impact on the climate.

All buildings are designed by local planners, with one common point of departure for optimal livability through: a/ comfort levels based on natural ventilation and use of daylight; b/ be zero energy or energy positive, and c/ with a

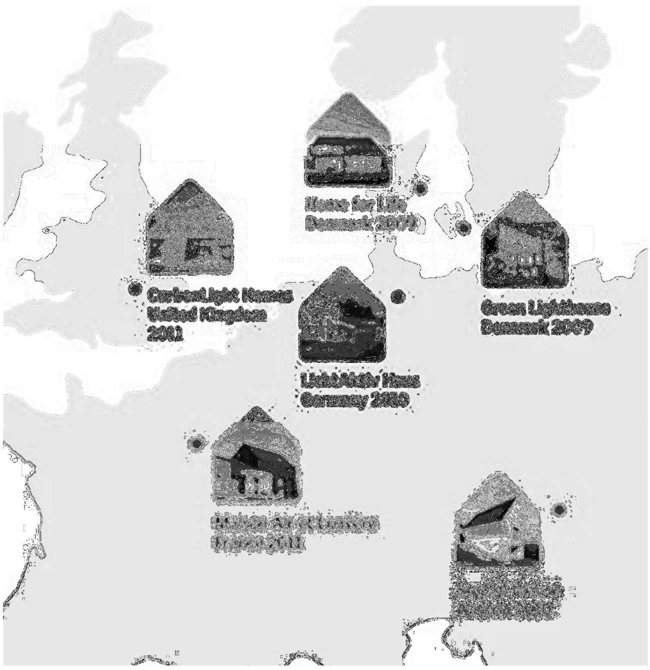

Figure 1- project overview

focus on the environmental impact, use of ressources and building footprint. The project programme target was set in 2008, to be responsive to the Energy Performance of Buildings Directive (EPBD), that new buildings in the EU should be `nearly zero´ energy, and basing mainly on renewable energy sources (Economy, 2013). The EPBD forms the paramount target of the programme, followed by the targets reflecting specific national targets with calculations basing on the individual country compliance tools and engines.

Sustainable indicator framework

An active house reflects on specific sustainable indicators, which are calculated in a tool and visually expressed in a radar diagram. The diagram shows the main categories, the three principles 1/ Comfort, 2/ Energy and 3/ Environment (fig. 2).

In each category there are 3 criteria, which are formed by sub criteria, e.g. 1.2 Thermal environment is reflecting summer (1.2.1.) as well as winter comfort (1.2.2). The tool enables a visual showing different scenario in one and the same diagram, thus making comparative benchmarks standing out.

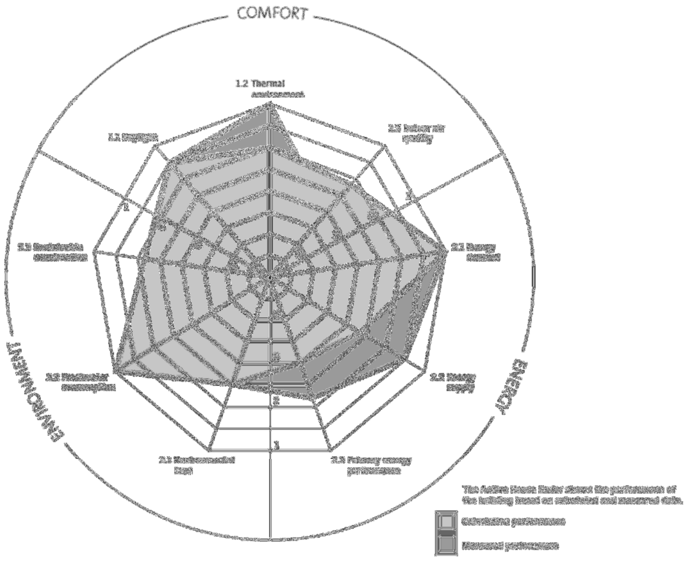

Figure 2 - Active house radar diagramme (Green Lighthouse)

The radar diagram is used as point of reference for the empirical data of this paper, in constellations with the findings from social sciences. The aim is to describe the theory of the programme, and to refer the actual performance to this, shown in one model. The active houses used as case studies in this paper are all local interpretations of a goal for optimal livability with a minimum of impact.

Reality check - real people in real houses

All the buildings have been monitored in use, on technical measures and user feedback and experience (Eleb, 2013), (Suschek-Berger & Tritthart, 2014), (Georgitsi, 2014), and via interviews for a book (Edwards & Naboni, 2013). The purpose was to check and balance the building performance, and, to gain insights on user experience, valid for qualification of future and for share of knowledge and experiences. First key learning was that there is little framework available from other demonstration projects for the sociological aspects. The sociologist team from Humboldt University were able to develop an actual scientific method, which has been applied to two of the projects (Fedkenheuer, 2013). The method works with the degree of the family´s well-being based on a three-dimensional structure of attitudes. The tripartite model distinguishes between three categories of reactions to attitudes: cognitive, affective and conative reactions, which can manifest themselves verbally and non-verbally and can be measured. Diary format in a digital logbook and a public blog (Oldendorf, 2012), both maintained by the family, recording their living conditions.

Approximately every 4 weeks the respondents complete an online questionnaire including both open and closed questions about the various dimensions of well-being. Every 4 to 8 weeks, more in-depth structured interviews are conducted with the parents in the form of video calls. This allows statements to be recorded in detail, and to be set into context with the respective evaluations (Fedkenheuer, 2013).
Longer structured interviews are conducted in the house at the end of each season. The team is monitoring via different investigative methods, figure 3.

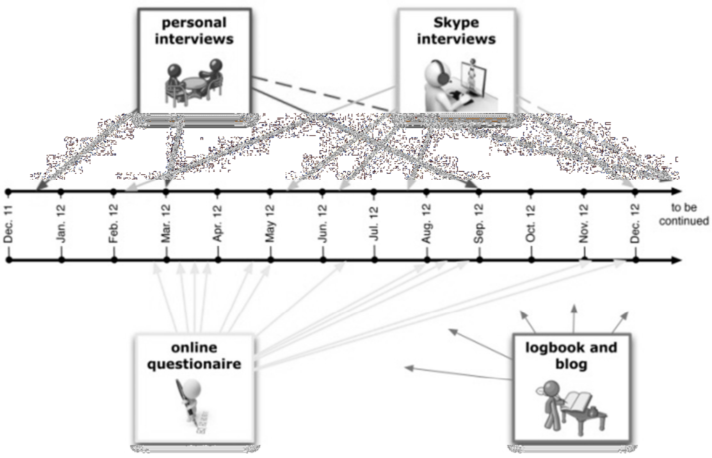

Fig. 3: Research design

Practice testing – Comfort
It can be proven that the aspects of automation as well as plenty of daylight and fresh air enhance the well-being of residents. This becomes especially evident with the project in France: some of the residents suffer from either asthma or pollen allergy and neither have had an attack or irritations. "The improvement in [his] health is a lasting one… No attacks, no Ventolin in the evening, because he had a background control therapy, but he no longer uses it. You would never believe that he was asthmatic". They attribute it to the dual-flow system of the house. Control of the air and the fact that the house appears to be so "healthy" is therefore perceived as an extremely positive quality (Eleb, 2013).

Practice testing - Energy
In order to be able to make a accurate comparison between the measured power consumption of the system equipment and the original calculations made in accordance with compliance tool submitted, a visual step-by-st ep tool has been used to follow the steps (fig 4.).

The tool uses as corner references the

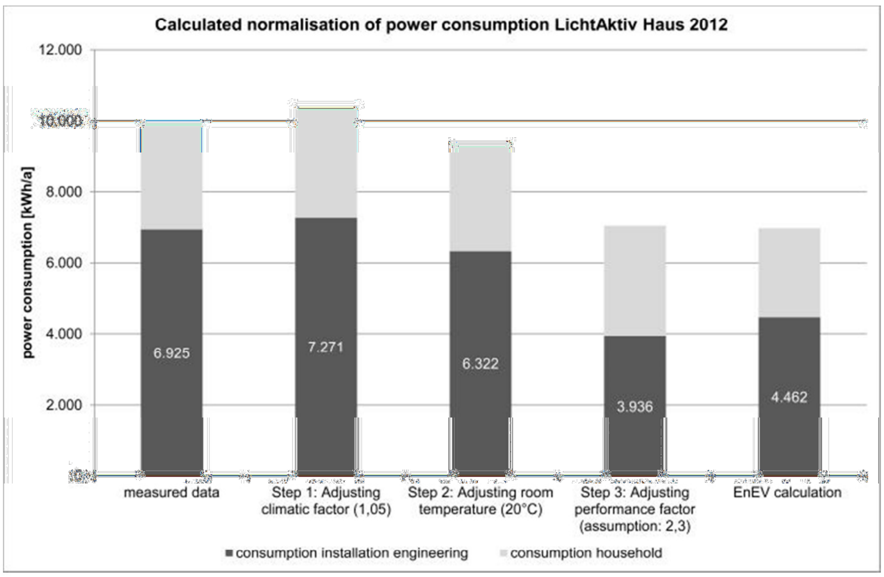

Figure 4 - step by step

measured and the designed values, and describes the steps in between, to get behind the reason for discrepancies. First step is degree days, next is difference in comfort temperature, and third step is the difference in efficiency working number of the heat pump – the coefficient of performance = COP (Wilken T., 2012).

Practice testing – Environment

The LCA calculation reflects the yearly consumtion and the different life stages of the project. The climate renovation project, LichtAktiv Haus saves the greenhouse gas emitted during its fabrication, maintenance and final disposal after 26 years of use (Hartwig, 2011)**. In arithmetical terms, the house has a neutral global warming potential at this point. The project thus confirms the assumptions that the utilisation of existing building structures and the use of sustainable raw materials in the construction have considerable advantages over new build.**

Sustainable living from a sociological perspective

From a sociological perspective the logging of environmental awareness and energy-consumption behaviour is a particularly interesting aspect of the evaluation. It was assumed that moving into the house and the interaction with it, e.g. via the consumption monitor, would lead to greater awareness in these areas and a more sustainable way of thinking. This assumption was confirmed to some extent, as occupants seem to be more aware of energy consumption in particular and it can be assumed that the house had a positive influence upon their environmental awareness. By having energy consumption and energy yield values quickly available through daily real time monitoring, and check, the occupants adopted an active consumption behaviour, parallel to the mental wellbeing of “not overspending”. So far, these behaviour patterns seem to be relatively consistent, so it is reasonable to assume that a long-term behavioural change will establish itself. The occupants' statement that they strongly identify with the sustainability aspect of the house and are proud to represent economical, sustainable living (Eleb, 2013) (Fedkenheuer, 2013).

Discussions

At a helicopter glance, the six buildings are wide apart in terms of geography, (latitude 55-48), climates (temperate, continental and oceanic), m² size (117 – 304), compactness, footprint and materials; the vernacular design approaches vary as do the cultural responses for typical middle-class family life. Nevertheless, the common denominators are distinct; generous daylight levels, from all corners of the world, as well as the principle of using fresh air to enable optimal indoor comfort. The technical features vary from use of automated natural ventilation, ventilative cooling with automated window openings, heat controls per room, CO_2 rates, humidity sensors, dynamic external solar shading, all linked to a weather station detecting the wind speed, solar radiation, etc. Detail differences within types of heat pumps, comfort levels in compliance data, u-values in the envelope, and different systems, brands, materials and system diagrammes. Common for all is that the users can override the system and take manual control of their indoor environment.

The results of the monitoring raise key questions as for practice of national compliance engines; firstly, the typical comfort level demanded by the users is 2-3 degrees higher than standard settings in compliance engines; secondly, the typical compliance figures focus mainly on demand for heating, however in modern sustainable houses being very energy-efficient, the indoor comfort is influenced by several other aspects; thirdly, the compliance data do not include the livability aspects of thermal comfort, which are paramount to users feeling of wellbeing and motivation to live and build sustainably.

Climate renovation – the real challenge

The facts that by 2050 70% of the world's population will live in cities, and 9 out of 10 currently existing buildings in Europe will still be in use, make climate renovation the key challenge. It is particularly important that the renovation solutions presented are reproducible across Europe; if the energy demand of the EU building stock could be cut by 50% by 2020, then this action alone would deliver the major bulk of the EU 2020 target for reducing CO2 emissions by 20%.

Combining qualitative and quantitative evaluations

Often, sociological evaluations are referred to as qualitative, i.e. non-tangible outputs, whereas the technical indicators are referenced as quantitative. However, the post occupancy evaluation carried out on the test families show a ranking rather than tangibility being decisive. The PhD thesis carried out across the projects (Olesen, 2014) suggests that the an understanding of the user role would be supported through more focus on perception and sensoric experience as value-adding attributes. Theory has it, that expert planners can demonstrate errors in planning when dealing with complex systems, typically focusing on individual topics, blind for other problems, thus missing the big picture (El khouli & Drexler, 2012).

Occupant´s answers to health related issues are imperial arguments, e.g. that your child has less colds, better sleep (Georgitsi, 2014) or can avoid medication for asthma (Eleb, 2013). If we would imagine a scaling of these aspects onto societal matters as e.g. health expenses, sick days, asset management, it would be possible to swift the agenda for a sustainable transformation in the built environment.

Initially the occupants attributed their enhanced livability primarily to the modernity and size of the house, but later they regularly referred to the brightness of the living areas as a contributory factor to their increased sense of well-being. It can be discussed that it is possible to influence living preferences by positive experiences. This observation is important as the human well-being aspect is can work as motivation of mass scaling sustainable development.

Conclusions

The point of departure for the 6 demonstration projects has been to prototype experiment and test how to develop the building mass sustainably. The short of the long is that it is possible to achieve zero energy in 2020, in new built as in a climate renovation. Even in buildings built and renovated 10 years earlier. Digging deeper, 7 main conclusions can be taken forward:

- ✓ *No conflict between low energy and high fenestration*: it is possible to achieve a good thermal performance in real use, also with high daylight levels. Good performance is achieved with automatic control of window openings and solar shading, the ventilative cooling from opening windows is particularly important.
- ✓ *Adaptation is king*: By use of the adaptive comfort principle, user comfort is programmed relative to the outdoor temperature. It is possible to avoid overheating through building design, rather than technological measures. Undercooling is accepted by occupants when they have direct influence on the between indoor temperatures and heating consumption.
- ✓ *Theory cannot stand alone*: Compliance tools results do not reflect a full picture of the degree of sustainability, energy demands and comfort levels differ vastly to theory. Environmental engineers should be aware of this factor, when programming capacity and adaptability of the systems.
- ✓ *kWh/m2/y – do not forget the /o (per occupant)*: Reviewing energy demand should also reflect footprint, i.e. assess energy demand per occupant, as space demand is also an aspect of sustainable construction. Currently the share of consumption seems relatively bigger in a smaller house than in a larger house.
- ✓ *Onsite production (also) pays off:* Good thermal comfort is possible, with solar energy produced on site. It is possible to initiate climate renovations without airbased heat recovery systems, sourcing renewable energy on site.
- ✓ *Sustainable significance of energy consumption*: Energy consumption is a detail aspect in a sustainable building, livability is the key comfort parameter.
- ✓ *Vernacular and individual*: A sustainable building can and should demonstrate cultural characteristics, giving priority to the architectural quality. The registry of sustainable tools and solutions must be instrumentalized to support planners.

Now we must diffuse and fertilize the building mass with the tested and proven solutions.

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