Defining challenges for future sustainable homes: A review of earlier experimental activities

Paula Femenías

Chalmers University of Technology, Gothenburg, Sweden

ABSTRACT: A renewed focus on innovation in the building sector calls for research strategies that will strengthen the position of holistic architectural knowledge for the benefit of a sustainable built environment. This paper presents research that focuses on future homes that will enable radical reduced resource use related to living. In order to reduce the environmental impact of living and dwelling we need to address not only buildings and physical structures but also user behavior and lifestyle choices. Contemporary housing development is defined by a view of the housing market based on surveys among limited groups of people and not on actual needs and wishes representing the wider population. Furthermore, the actual housing market does not deliver structures that will enable sustainable changes to the environmental impact of living.

The aim for the paper is to define architectural research for future homes in relation to a planned purpose built Living Lab. Research should support a radical reduction of the environmental impact of living. A review of 20th century housing research and development in Sweden and France provides insights from previous successes as well as failures in the field. Results point to the importance of involving end-users and to build on solid understanding of the use of homes. In addition, already explored innovation regarding space use can with advantage be repeated, as contemporary users are likely to react differently than users did in the past. We propose a three-step model for research starting with empirical studies of the use of homes among a large variety of households (i.e. regarding size, age groups, cultures etc.), prototyping of new architectural concepts (e.g. related to layout, interiors, equipment, products etc.) and test and evaluation of these in the Living Lab.

KEYWORDS: Living Lab, future homes, resource efficiency, dwelling habits, user involvement

INTRODUCTION

At present, the building sector is concerned with most major societal challenges, including objectives for sustainable development, climate change, environmental protection, increasing urbanization, globalization, adaptations to changing demographics and anticipated large scale refurbishment of post-war housing. These challenges call for the development of new norms and practices and are among the main drivers for a renewed focus on innovation, not only in the building sector but in society at large.

The housing sector largely contributes to the national environmental footprint. Swedish households accounts for a fourth of the total national energy use and has been pointed out as a main area for action in order to reach the national goals for energy saving set for 2020 and 2050 (Environmental Agency 2013). Since the 1950s, household expenditures for housing and transport have each increased by almost 300% (Söderholm 2011). In addition, Sweden had in 2008 the highest spatial use per capita in Europe with 42,5m^2/4574.7ft^2 per person, and the highest number of single person households (44%) (Dol and Haffner 2010). A recent study states the use of floor space as one of the most significant indicators for energy use in housing (Hille, Simonsen, and Aall 2011). The larger number of single person households also increases the total electricity use per capita (Elforsk 2006). Consequently, these contemporary living trends are in opposition to sustainable development.

Sweden has in recent years shown remarkable innovation in low-energy construction (Femenías and Kadefors 2011). These innovations regard mainly the adoption of technology and adaptation of construction methods. Alternative concepts for the design and layout of dwellings and homes that enable changes in priorities and lifestyles have not been subject to the same development, and still signify a more radical change of mind-set. A number of authors have claimed that economically justified energy-efficiency improvements will increase rather than reduce energy consumption (Sorell 2009) thus we question how advantageous energy-efficiency measures in housing design are when seen from a more holistic standpoint. Rebound effects of efficiency include the increase of embodied energy due to higher levels of insulation but also re-spending effects when households increase consumption of energy demanding goods and services as a direct result of cost-savings from efficiency.

20th century Swedish housing development led to a large increase in standard, comfort and quality of life for the wider population and was a corner stone in building the well-fare state. Central was knowledge about the use of homes and the needs of the users. Observations of mainly women using home environments was carried out by the national 'Homes Research Institute' 1944 until the early 1970s and led to new standards linked to generous loans for the construction of housing. These standards were transferred to the formal building regulations in the 1970s. Until the 1990s national surveys were regularly carried out about living and dwelling habits. In the early 1990s large changes in the national state's involvement in housing and construction led to the abolishment of finance for housing development and a deregulation of housing standards and no more national survey were carried out. Instead, contemporary housing standard and design are determined by norms within the sector, market surveys which map customers' willingness-to-pay, and regulations which do not sufficiently reflect the urgency to reduce energy and resource use (Hagbert et al. 2013). In fact, very little has changed regarding the typology and layout of Swedish housing since the 1970s, even less so to adapt to a growing awareness of the environmental and social impact of the built environment.

1.0 RESEARCH CONTEXT

1.1. Challenges for housing development

As outlined in the introduction, this research aim at merging two strands of importance for the planning of future homes. First, we have observed a lack of focus in recent housing development for holistic solutions which enable radically reduced resource use through changed habits and mind-sets. Second, contemporary housing planning suffers from a lack of knowledge about the actual needs of the wider population and their use of homes (Nylander et al. 2011). Through merging these two approaches we aim at reaching beyond a narrow focus on efficiency and belief in technological solutions by enabling radical changes in the way we perceive and use homes.

The introduction of new concepts, technology and systems in the building sector and the fulfillment of political ambitions have often been approached by experimental activities and demonstrations. During the 20th century national governments in many Western countries financed construction innovation as part of post-war re-building, industrialization and modernization of society. Considerable experimentation was concerned with industrialization to improve production rates but experimentation also focused humanistic aspects of housing. In the 1960s the US Government paid attention to the development and launched 'Operation Breakthrough' in a bid to mimic the fast development of industrialized production in Europe (US Government 1976). At times, specific problematic and politically important areas have been subject to experimentation, not least the search for energy efficient construction and the application of new energy sources in the built environment.

At present, we find advancements in housing innovation to be low. We explain this by lack of governmental finance and incentives for innovation and development, and aversion to economic risk related to experimentation in market-led development. In order to tackle problems related to households' resource use we see a need for increased innovation in housing development. The Swedish Government has announced considerable increase in finance for research in the built environment in the up-coming years through transdisciplinary programs where industry participates in and partly finances research. Furthermore, there is a renewed interest in user-centered Living Lab settings as a means to address sustainability (Liedtke et al. 2012).

1.2. Aim and method

The aim for this paper is to develop strategies to advance research on future homes in relation to a planned purpose built Living Lab on the campus of Chalmers University of Technology, Sweden. Based on a review of 20th century housing research and development in Sweden and France, we give an outline for research in which we build on experiences from previous successes as well as passed misconceptions and failures. We also describe the kind of architectural experimentation which was researched in the past and the innovation i.e. implementation on a broad scale, from these.

Sweden never had any large national programs for general housing experimentation and innovation which was the case in for example France and the Netherlands (Schuyt and Blom 1994). As a reaction against the monotony of post-war large scale estates, countries such as the Netherlands and France invested in national programs focusing on quality and architecture in innovation of housing. Sweden, on the one hand focused housing research on developing empirical knowledge of the use of homes. On the other hand limited experimental activities have been driven by specific problems reflecting needs of the time (e.g. energy saving in the 1970s) and not seldom financed by the industry itself. To give a comparison to Sweden we present housing development programs in France. France has been chosen for the richness of data on housing innovation.

The method for the review is literature studies. We present preliminary results in-depth studies will be needed to secure the validity of results. Our focus is on housing for a broader public, which in Sweden and France means multi-residential blocks. Furthermore, most of these innovations have been carried out in public housing, or housing developments which has profited from governmental finance.

1.3. A purpose built Living Lab

A Living Lab is planned in collaboration between the academy, a cooperatively owned national real estate company, a larger nationally operating architect office, a science broker between the academy and the local industry, and a facility managing company at the campus. The Living Lab will include both student accommodation and research facilities and is financed through the European Climate-Kic program, and in part by the real estate company and the architect office. The student accommodation and the research facilities are not necessarily occupying the same space in the facility, but both respond to needs of the campus. Furthermore, the Living Lab is part of the SusLab NWE research program (www.suslabnwe.eu) with similar living lab facilities in other European locations. Focus for the Living Lab and SusLab NWE is radically reduced resource use in future homes through the meeting between technical and behavioral science.

The Department of Architecture has not been among the initiators of the project, which is the Department of Civil Engineering, but has been invited to take part. The question has been to define research which will advance architectural knowledge. Researchers from both Departments belong to an interdisciplinary research environment called *Homes for Tomorrow*.

This paper is one of several publications in which we define an architectural approach to living labs. We cherish the idea of co-creation of innovation between end-users, industry and academy, something which is also strongly favored by scholars in the emerging field of living lab literature (Leminen and Westerlund 2011). In an earlier paper we have explored the concept of a Habitation Lab, a laboratory for experimentation in habitation (Femenías and Hagbert 2013). We refer to similar laboratory experiments as the 'PlaceLab' at MIT (www.architecture.mit.edu/house_n/placelab.html) or the Norwegian design experiment 'TreStykke' (Thomsen and Tjora 2006). We also emphasize that the Habitation Lab will support learning and the development of shared values and frames of reference among students, researchers, and industry partners and thus support a social learning process, on personal and professional levels.

A paper by Bannova et al (2013) focuses on the idea of integrating a design studio in the planned Living Lab preferably a design-build-live project in which students will be engaged to design, partly build, and experience the habitation by living in the studio during a time-period.

The design of the planned Living Lab is in-itself an architectural challenge, not least as it is planned to be moveable (being granted a temporary building permit) and should be usable in whole or in parts in other locations. Furthermore, the lab should be designed in order to accommodate changes to exterior walls, interior settings etc. as part of technical experiments and research. These are all interesting topics for architectural research. However, as part of the *Homes for Tomorrow* research program, our research interests are sustainable housing and living environments.

2.0 REVIEW OF EARLIER HOUSING DEVELOPMENT

2.1 Swedish housing development

The social political program of constructing a 'People's Home' with good housing for everybody was launched in the 1930s as a corner stone in building a well-fare state. Interrupted by World War II the ideas were implemented in the late 1940s and 1950s. The architecture, created by prominent architects, a committed industry and generous governmental finance, resulted in what has been called the 'golden age' of Swedish 20th century architecture.

Central to developing the 'People's Home' were functional studies carried out in laboratory environments in which mainly women were observed when carrying out housework. The result was standards dictating minimum spatial requirement to ensure good functionality and hygiene. The results are good living qualities which are still appreciated today.

Housing innovation has been defined by the needs of the time. The period 1965-1975 was characterised by massive housing production focusing on industrialization and large-scale development. As a result of the first energy crises, national experimental programs were launched which focused on new energy solutions for housing.
Besides national programs, there have been grass-root activities for housing innovation, not least eco-villages which emerged in the 1970s and 1980s. SABO the umbrella organization for public housing has also financed research with limited budgets, for example in relation to participatory design emerged during the 1980s and 1990s.

At present the housing sector is concerned with challenges regarding changing demographics, affordability and sustainability. Low energy housing had a breakthrough in the first decade of the 21st century and now we see an increasing interest for social sustainability.

Flexible layouts, extendable homes, co-housing and shared facilities are ideas which has been tried out in the past and now have renewed actuality to limit the environmental footprint of housing. Earlier experiments show that flexible and extendable solutions worked for some time but quickly became fixed. Co-housing has re-emerged but rather than decreasing the space use, new co-housing increase space use as shared facilities are built at the same time as individual units have necessary facilities separately. The modern co-housing builds on facultative and not ideological sharing. Shared facilities for example common laundry rooms were standard in Swedish housing (public or private) until recently but are now disappearing. Modern requirements for comfort and privacy work in opposition to environmental sustainability.

Table 1: A selection of housing experiments in Sweden ~1940-2010.

Experiment	Year	Experiences
Extendable 'elastic' flats	1940s	One small flats between two could be added or separated – this soon became fixed.
Flexibility with moveable walls	1951	Flats that could grow with the family – the walls later became fixed.
Compact living	1950s	Including sliding walls and in some cases American kitchens to make very small 3-room-and-a-kitchen flats of approx. 50m2.
Shared facilities	1958	Four atrium housing encircled a 'mother-cell' for meetings, guest rooms and washing.
Concrete three-level slab construction with wooden villas	1960	The villa could fill the plot as the family grew – today all plots are fully built.
Eco-villages	1980s-1990s	Bottom-up and normally resident-owned. Eco-cycle thinking and community development.
Participatory design	1991	39 families participated in the design of unique building in Malmoe. Owned by the public, managed by the residents.
Cohousing	2008	Common rooms and fully equipped flats for elderly.
Housing with social spaces	2010	Cohousing from the 1960s revived with space for meetings but no obligations for sharing.
Compact living	2012	Single student house of only 8,8 m2 and small garden. Do not comply with regulation – no further implementation.

2.2. Experimental activities in France

Early support to industrialized production made France a champion in the field in the early 1960s. The results were quickly subject to national critique over deficient quality. Furthermore, the results were not as innovative as planned and experiences were difficult to implement as the sector went from producing millions of homes to areas with only a few hundred dwellings.

A recent publication gives an overview of the experimental activities driven by the governmental body PUCA during 40 years (PUCA 2012). The program was launched to create qualitative innovation to counterbalance large-scale developments of the 1960s. PUCA involved research driven by: experiments (testing of ideas); industry (production issues); concept/procedure (e.g. architectural innovations) and politics (e.g. environmental issues).

PUCA had different focus over the years. In 1973, activities were orientated towards energy efficiency. In 1978 a more experimental phase was introduced and a program called REX-'Rélisations Expérimentale'. The first years of the 1970s, an era with technical innovations was inspired by three-dimensional 'meccano' systems and morphological studies. The latter part of the 1970s found inspiration in the city/urban challenges. With the arrival of a new director in the 1980s the direction changed towards a more humanistic approach, combing architecture and engineering with social and behavioral sciences. A usability approach to architecture was implemented in the program Habitat-88 having several projects with participatory design. In 1987, the 'Europan' competitions were installed. Through the years, Europam fostered a whole generation of architects and got the careers of e.g. Jean Nouvel and Gilles Perraudin started. During latter years, environmental issues (HQE-High Environmental Quality), urbanization, rehabilitation and changing demographics have been on the agenda.

Table 2: Examples of French experimental housing (Léger 1990; PUCA 2012).

Experiment	**Experiences**
Flexibility	Moveable elements quickly become fixed.
Extendable flats (flats unified/separated)	Difficulties to liberate two flats at the same time.
Polygonal apartment layout	Generally appreciated, difficult to furnish.
Open kitchen-living room	Visual disturbances, hard work to keep order among belongings (need of house-keeper!).
Entrance hall or not (enter directly in living room)	Efficient space use, no place to keep clothes.
‘gradins-jardins’, pyramidal housing with terraces	Appreciated among residents, improved use of outdoor space.
Double height apartment	Light and airy; Noisy, draughty, difficult to furnish.
Private, semi-private, public space	Well implemented ideas.

So were these innovations successful? Not all innovations were that successful. One reason is the lack of systematic evaluation, also over longer periods – more than 1-2 years (PUCA 2012). However, the lack of evaluation is not the only inhibiting factor. New technologies have been opposed by established markets, for example heat pumps and solar energy in the 1970s and 1980s. Further, some novelties were not accepted by the users. Legèr (1990) notes that inhabitants of public housing are not the appropriate costumer for radical housing innovations. Higher social class inhabitants are more likely to appreciate these architectural qualities. Legèr reports that inhabitants for ‘Nemausus’ designed by Nouvel were specially selected by the public housing manager thus overlooking the queuing priority in order to get the ‘right’ tenants.

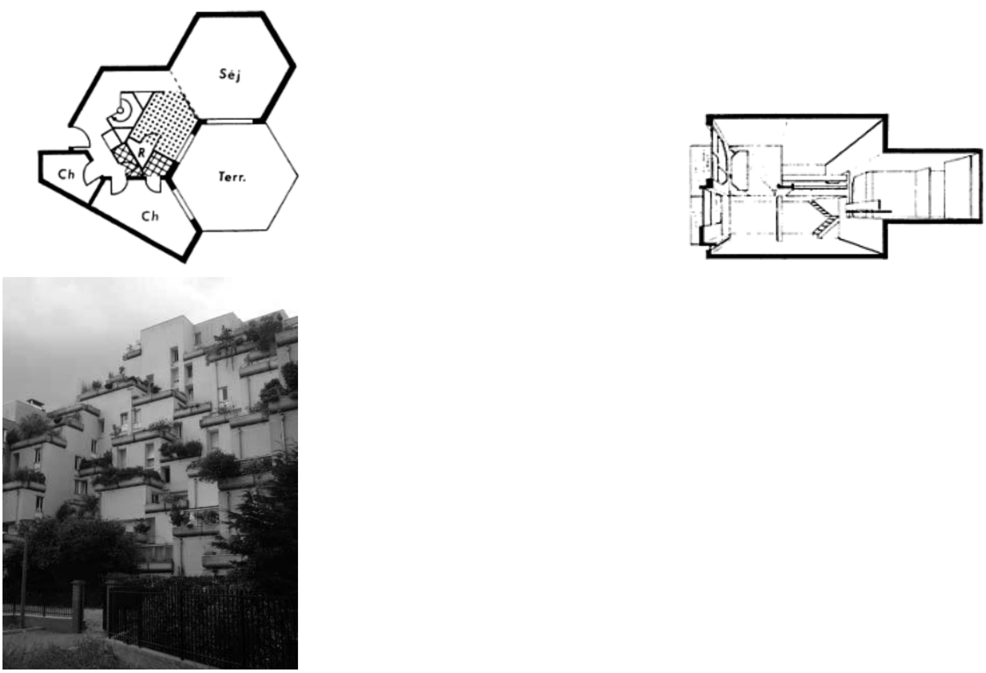

Figure 1: Examples of experimental housing in France. Left, hexagonal flat, Eventard/Angers. Middle, flat with double-height, Isle d’Abeau. Source: (Léger 1990); Right, ‘Gradins-jardins’/Cité des Pyramids, Villepine. Photo: author

2.4. Comparison

A comparison of Sweden and France shows different approaches to housing innovation were France has invested in large programs. However, results of individual architectural experimentations, e.g. flexibility and extendable flats are the same. Building experiments reflect the needs and prevailing ideological stances of the specific time, a development which is mirrored in both countries. We also note that the same kind of ideas reappear in cycles. Cohousing was part of socialistic ideas in the early 20th century, revived in the 1970s, and is now subject to interest to break the solitude of a growing number of single households.

Both countries show the importance of involving the user in order to reach broad acceptance and implementation of innovation. In Sweden this succeeded due to empirical understanding of the use of homes. In France we can state failure as housing innovation was proposed by architects and did not fit the users of public housing.

We can state that although many ideas for spatial experimentation have already been tried out, also repeatedly, this is probably no reason to rule out new trials of the same, and for that time avant-garde, ideas (e.g. double height, flexibility, extendable flats). These innovations might be more successful with contemporary users which have another mind-set.

CONCLUSIONS

Results of our review show the importance of involving end-users in housing innovation and to build on solid understandings of the use of homes among a wider population. As a conclusion, we propose an outline for research for future homes in three steps. The model is suitable to implement in relation to the planned Living Lab involving industry partners, and correspond to methods within the SusLab network.

1. Empirical studies of the use of homes (carried out in real homes using modern sensoring technologies) among a large variety of households (i.e. size, age groups, cultures etc.).
2. Design and prototyping of new architectural concepts in collaboration with invited industry partners in Living Lab. We propose experimentation on topics such as optimized living space, increased use of shared facilities related to layout, interiors, equipment, products etc., and focusing on different functions within the home (e.g. culinarities, rest, work, social interactions etc.). We propose experiments which have already been tried out in the past as these will be researched in new contexts and with users having a different mind-set.
3. Testing and evaluation of prototypes in the Living Lab with selected groups of users.

Among the limitations for the strategy are long-term uses which cannot be tested in the Living Lab (e.g. extendable solutions, changed user configurations). Furthermore, the involvement of industry could potentially inhibit the possibilities to radically question the very basis of contemporary market led housing development.

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