Knowledge transfer from professionals to end-users in the building hand-over phase

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Abstract

The Norwegian research project "Evaluation of housing with low energy need" (EBLE: 2012–16) studied the building process, measured energy use, indoor climate, and user experience in seven low-energy housing areas in Norway. The data sources in this paper were provided from seven group interviews of professionals involved in construction processes and 38 interviews of the occupant of the houses.

Previous studies found that there are gaps between calculated and measured values for energy use and indoor air temperature in new low energy buildings. The discrepancies are often especially large during the adjustment phase of the first year(s). The hand-over phase and the following period are critical as the occupants are adjusting to the building and influencing the performance of the building through their behaviour. This early phase is essentially the time during which occupants develop habits and new ways of interacting with their home. This behaviour is found to be largely impacted by the level of information about the dwelling the user has received, and sometimes directly translates into positive or negative end-user experiences.

This paper aims to investigate which processes are implemented in the hand-over phase and how this period can be used to inform and help the occupants', both to understand and use the technologies present in the building. The main questions regard how knowledge on the building and the technology is transferred from the professionals to the occupants in the building hand-over phase. How does the occupants' knowledge and level of information about the technologies affect the way the building is reportedly used, and thus, how does it contribute to shaping habits in new housing environments?

The findings of this study indicate that there are several unexploited opportunities in the hand-over phase, where professionals could contribute more to enabling the occupants to become proactive users who can control, understand and use their new environment in a more efficient way. A greater focus on motivating professionals to transfer knowledge and increase occupants' awareness of the consequences of their practices, may contribute to shaping behaviour that reduces use-gaps in the first phase, thus, leading to better agreement of energy- and comfort- related behaviour and consumption over a long-term period.

Introduction

There exists a well-known gap between predicted and actual performance of energy efficient buildings. This is especially true in the first years of operation (Hinge at al. 2008) where in most cases the actual performance is quite different from predicted performance (Larsen et al, 2010; Gram-Hanssen & Hansen 2016; Dokka *et al.* 2011; Goodhew 2016). There is also often a wide variation in energy use between households living in the same type of housing. For instance, Gram-Hanssen (2010) has shown how different user behaviours in identical houses resulted in a three times higher energy consumption for heating.

User behaviour is one of the main causes for observed discrepancies in household energy consumption (Larsen *et al.* 2010; Gram-Hanssen & Hansen, 2016; Dokka *et al.* 2011; Goodhew 2016). This is because occupants affect a large array of parameters including the choice of indoor air temperature (commonly

higher than calculated), the use of warm water, and the use of technical appliances. Other factors that are found to influence energy consumption are linked to the type of technical solutions implemented including user-interface design, less effective performance of technical installations than anticipated, or poorer construction practices (e.g. air tightness, thermal bridges).

User behaviour is a complex field influenced by cultural, social and psychological factors as well as personal attitudes and household economy. In addition, the level of ability to understand technical solutions such as ventilation and heating systems and the usability of the user interfaces, affect building use but also the level of satisfaction of the occupant and the overall building performance. Regarding the latter, the hand-over phase from the professional to the occupant is found to be critical. The level of information provided by building developers to users and the understanding of functions and intended use, lead to positive or negative end-user experience and thus, directly impact building performance (Mlecnick *et al.* 2012).

During the period of time after first moving in, occupants start to adjust to their new home and develop habits that may affect its performance. In this phase, occupants will develop their way of interacting with the new housing environment as well as its integrated technologies. How the nature of the technologies and their integration shapes user behaviour, is an important discussion within the field of socio-technical studies (Gram-Hanssen 2010).

The role professionals take in hand-over processes when introducing new technologies to occupants and the consequences on determining user practices and satisfaction is little explored. Professionals may sometimes not understand the key role they have in communicating purpose and use of technology to residents. Furthermore, the incentive for motivating residents might be low and professionals may also show little interest in investing time and resources after the hand-over process is completed, especially since there are no obligations to fulfil the ambition level associated with a building.

OBJECTIVE

This paper looks at the meeting-point between professionals and occupants. The main objective is to investigate the procedures followed in the hand-over phase, and how these will influence the users' knowledge of the buildings' technology, as well as shaping habits.

The main questions are:

- How is knowledge on the building and its technology transferred from the professional to the occupants in the building hand-over phase?
- How do the occupants' knowledge and level of information about the technologies affect reported use, and thus contribute to habit shaping in the new housing environment?

Literature background

ENERGY CONSUMPTION GAP IN ENERGY EFFICIENT DWELLINGS

Literature in the last decade has repeatedly highlighted gaps in actual energy performance of low-energy housing compared with expected results from energy simulations. There are commonly wide differences in energy use between households even when living in the same type of housing with the same technical infrastructure. User behaviour and every day practice in relation to the housing environment are found to be one of the important reasons for observed differences in household energy consumption (Larsen et al, 2010; Gram-Hanssen & Hansen 2016; Dokka *et al.* 2011; Goodhew 2016).

Gill *et al.* found that occupants' behavior accounted for respectively 51 % and 37 % of the variance in heat and electricity consumption in houses. Interestingly enough, user behaviour studies show that the energy profile of buildings is not the primary motivation for people to live in these places, and this might also be a reason for why users do not always behave in the most energy efficient way (Thomsen *et al.* 2012).

An explanation of the gap between actual and predicted energy use is offered by the "rebound effect" which describes an increased use of energy in houses where energy efficiency measures are applied. For instance, energy efficiency measures reduce energy costs for home heating, meaning that the costs (and energy) saved by heating can be spent on other appliances (Galvin 2015).

Gram-Hanssen & Hansen (2016) studied energy use in highly insulated buildings contra lesser insulated buildings. Findings indicated that inhabitants of energy efficient housing used more energy than anticipated, while inhabitants of housing with low technical standards commonly used less than anticipated. These results support assumptions that user behaviour is not unique and instead, is adapted to the buildings' energy standard (Gram-Hanssen & Hansen 2016). This also implies that focusing solely on energy efficient measures in housing is not sufficient for reducing energy consumption, and will not reduce the gap that is typically found when comparing theoretically calculated and measured energy consumption. Gram-Hanssen & Hansen (2016) concluded that aspects such as social, cultural, and behavioural issues need equal focus when attempting to reduce household energy consumption.

In this regard, household practices and interactions with integrated technologies are of interest. Mlecnik *et al.* (2012) found that the interface design and explanation of control devices' functions had an influence on user satisfaction and perceived control of one's environment. The findings from different evaluation studies repeat recommendations that improved information, training, and education should be given to the occupants during the hand-over phase in order to use the opportunity to engage households into energy saving (e.g. Galvin 2015). Most often, the information given to the occupants is often perceived as insufficient (Mlecnik *et al.* 2012; Hauge *et al.* 2011).

The professionals' practices in terms of technology dissemination and providing information are little explored. Keul (2010) found a clear correlation between level of satisfaction, technology dissemination and improved performance of the building. Furthermore, the context of the introduction of a new technology seems to have an influence on how it is adopted and integrated into household's practices (Gram-Hanssen, Heidenstrøm, Vittersø *et al.* 2016).

The need for specific user instructions regarding use, operation and maintenance of heating and ventilation systems in passive houses was also stressed in Mlecnik (2013). Barriers rooted in lack of understanding of operation of heating or ventilation could be reduced by specific information and more

effective communication with occupants (Mlecnik 2013). The lack of instructions on adequate use of for instance heating and ventilation systems, are typical reason users mention when having problems with the operation of their dwelling (e.g. Schnieders and Hermelink 2006; Isaksson 2009; Thomsen *et al.* pending). Schnieders and Hermelink (2006) also stated that the results of informing people are often better if a qualified person explains and demonstrates the handling of the system, rather than providing written information. Isaksson (2009) pointed out that users seldom read complicated technical descriptions, especially if they themselves have no interest in technical innovations.

Owen & Mitchell (2015) stated that the role of technology installers for influencing energy behaviour is an underrated opportunity. Moore, Haines, Lilley et al (2015) explored a user-centred design process to improve the introduction of heat pumps to users in order to increase acceptance and promote efficient use. The shift of focus from the technical aspect of new systems to recognising the role and importance of the end-user's experience and needs, is described as a key step in integrating new technologies.

Gram-Hanssen, Heidenstrøm, Vittersø *et al.* (2016) studied how the context of the introduction of heat pumps influenced the way it became a part of the occupants' daily practice, and thus to what degree technology adoption was followed by energy savings. They pointed out three main aspects relevant for understanding why the new technology often failed to deliver the expected savings: (1) physical location and integration into the home; (2) changes in heating practices and comfort expectations due to the new technology; and (3) users' knowledge and competences related to operating the new technology. Understanding the role of the installation technician is important for the integration of technologies such as heat pumps into households' everyday life (Moore *et al.* 2015; Owen *et al.* 2015). However, often the complexity of technology was a barrier to its correct use, especially in elderly low-income households (Owen *et al.* 2015).

APPROACHES

An approach that focuses on how technologies are or are not intended to be used, is known as script/anti-programs. The theory behind that approach is that objects come with inscriptions and intentions of the designer. Users' negotiation with the designer's script will take place and ideally the script is followed. However, sometimes the "script" is not correctly followed or the users will even revolt against it: "In these cases they develop their own anti-programs, which lead to unexpected uses" (Berker 2011). Gram-Hanssen, Heidenstrøm, Vittersø *et al.* (2016) stated that the context of the introduction of new technology seems to have an influence on how it is adopted and integrated into household's practices.

Svane (2002) described that in everyday life, it is difficult for occupants to change habits even if they are well informed and motivated. However, in situations where people make certain fundamental changes in their life, such as moving to a new dwelling, they may be more receptive to making other change as well. Svane calls these situations "Window of opportunity".

"Soft-landings" is a framework that was born out of the observation that the building industry seldom learned from the buildings they produced, while at the same time the owners often experienced that their new building did not meet their expectations. The framework especially emphasises the significance of the hand-over phase and the general problem with separation of construction and use phase is summarised as follows: "the rigid separation between construction and operation means that many buildings are handed over in a state of poor operational readiness and suffer a 'hard landing' … Problems can be worse where complicated or unfamiliar techniques or technologies are used and nobody can understand why …" (UBT&BSRIA 2009).

Soft-landings proposes a continuous procedure that provides additional support as early as in the procurement process and lasts long beyond project completion. The goal is to smoothen the transition into use and to raise awareness of performance during operation already in the early planning phase. The main procedure is divided into five stages: briefing stage, design development, pre-handover, aftercare in initial period and aftercare year 1–3. The actions taken in the stages are to set and manage expectations, review experience and likely performance, involve different actors and users, etc. The different actions and activities are defined in checklists (UBT&BSRIA 2009).

Research methods

The Norwegian research project "Evaluation of housing with low energy need" (2012–2016)[1], examined the building process, measured energy use and indoor climate parameters, and evaluated user experience in eight low-energy housing areas in Norway (case 1–8) in a total of 74 households (of which 59 passive houses, 5 zero energy houses, and 10 low energy houses).

In order to investigate occupants' and professionals' experience of living, planning and constructing energy efficient houses, group interviews were conducted with 18 individuals involved in the construction process as well as 38 in-depth interviews with the occupants of these houses. Out of those 38 interviews of occupants, 27 were carried out at their homes while the remaining eleven occupant interviews were telephone based interviews. Interviews were semi-structured (Kvale 1996) and those with the professionals included questions on their experience with the building process, challenges related to energy efficient construction and questions on information provided to the occupants. The questions regarding the information provided during the hand-over, were mainly answered by the *project manager* or *project leader*. Since the interviews with the professionals were group interviews, the other participants in this group situations are also listed (Table 1). The interviews with the occupants focused on experience of thermal comfort and indoor air quality, use of technical installations, general practices and satisfaction, and information received. The topic regarding provided information was only one of the topics of interest in this project. Only in hindsight, when reflecting on interview data, was it found to be one of the most interesting topics because of how little explored it is research literature. The interviews lasted for about one hour, were audio recorded and notes were taken. Themes and opinions were grouped, analysed and discussed within the project group of researchers.

1. http://www.lavenergiprogrammet.no/kunnskapsbank/forskning-pa-passivhus/.

Table 1. Number of interviews with households, number of interviews with professionals, description of professionals' roles, comments.

	No. of households interviewed	Interviews professionals (key personnel involved in planning and construction)	Comments
Case 1	5	4 (project manager, project leader, architect, foreman builders, building manager)	Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 2	4	3 (project manager, project leader, foreman builders)	3 face-to-face interviews occupants. 1 telephone interview. Professionals: Face-to-face. Recorded. Notes.
Case 3	2	2 (head of firm, project leader)	Occupants: telephone interview. Professionals: face-to-face interviews. Recorded. Notes.
Case 4	2	2 (project manager, project leader)	Occupants: telephone interview. Professionals: face-to-face interviews. Recorded. Notes.
Case 5	5	2 (project manager, project leader)	Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 6	12	2 (project manager, project leader)	6 face-to-face interviews with occupants, 6 telephone interviews. Professionals: face-to-face interviews. Recorded. Notes.
Case 7	3	3 (project manager /leader, architect, consultant energy)	Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 8	5	(same housing developer as in case 2)	Occupants and professionals: face-to-face interviews. Recorded. Notes.
Total	38	18	

Findings

The purchasing phase is where the occupant to-be and the developers meet. The main issues investigated in this paper are first if there are unexploited opportunities in the hand-over process which would allow for preparing occupants' adaptation to the new energy technologies and better integrating them into their daily practices. The second issue regards how professionals can better contribute to enabling the occupants as active and conscious agents in controlling, understanding and using their new environment.

The interview data is presented in table 2 where the information retrieved from housing developers' key personnel and occupants can be read side by side. The perception of the hand-over phase can thus be easily compared. The section on housing developers' is divided into the categories of "attitudes", "type of information" and "first year after hand-over". The attitude and understanding of user needs is anticipated to influence the type of information provided. The first year after hand-over category points out the professionals' experiences with needs, questions, and problems after the occupants started exploring their new environment. The section on occupants is divided into "occupant experience" with information received, "want more" and "want less" describing how the type of information was perceived from their point of view. Quotes that illustrate the occupants' experiences that are given in the text below Table 2. After that, a short section on measurement results gives an overview of the buildings' actual performances.

The attitudes of the housing developers towards the need of information and training in the hand-over phase varied. The housing developers of case 1–4 did not adjust their hand-over procedures to passive houses. The procedure was standard. The interviewees in case 5–7 did not give specific information on how they approached the hand-over phase. The developer of case 6 had the most customer service-minded approach among the studied cases. All housing developers provided an information sheet and user manuals. Most of the occupants got a short introduction of how to use the technical installations. Suppliers were sometimes involved in hand-over procedures. Most occupants wished for more information and different types of information, especially in the cases where the dwellings contained innovative solutions that were new to the occupants.

Many occupants were interested in learning more about the specific technical standard of their dwelling (passive house, zero energy dwelling) and whether the technical standard brought with it any implications regarding the use. According to the housing developers, the technical standard was of little focus during the buying process since they experienced that the buyers valued other aspects higher. However, the buyers demanded information on technical standard after having bought. The interviews revealed that expectations towards a new, energy efficient home were high, and especially in terms of thermal comfort. The technical standards' energy saving potential was appreciated, however in the least cases a motive for buying. Many interviewees described the energy saving potential as "bonus" for the environment and for household economy as they expect reducing costs for heating. The housing companies experienced that comfort is a main sales argument. Some professionals interviewed had earlier tried to advertise environmental friendliness of passive houses, but received little responses from potential buyers. Comfort sold better than environmental issues.

When being asked on information they received, some occupants were satisfied:

Table 2. Interview data on housing developers and occupants perspectives on information giving and need at hand-over.

Case number, Energy standard, Type of housing, Type of ownership, Information on heating- and ventilation system	**Housing developers: Information at hand-over**	**Occupants: Experience with information and information need**
Case 1 Norwegian passive house standard, Single family-houses, Freehold housing. Air-liquid heat pump serving 1 radiator per floor and hydronic floor heating bathroom. Balanced ventilation with heat recovery.	**Attitude:** – Should be no difference in use of passive houses than of other housing built according to current technical standard (TEK 10). There should be no additional need to provide information and going through use. **Type of information/offers:** – Go-through with all occupants at hand-over. – Digital user, maintenance and operation manual. – Additional information on how heat pumps (air-to-liquid) work, plus standard information from Norwegian Home Builder's Association on passive houses. – Offer: Heat pump service and subscription for regular change of ventilation filters. **First year after hand-over:** – Technical faults with radiators. Occupants contacted them. One house was sold: the new owner asked about information on passive houses.	**Occupant experience:** – Received information manual. – Short hand-over meeting with general information. – Some occupants asked for a short go-through of the ventilation system (others didn't). – In total, content with information received. – Received help and advice during first year when asking for, this is rated as positive. **Want more:** – More information about the passive house concept. – Wished for more user-friendly ways to learn about use and possibilities of technical installations. Suggested apps and videos – Knowledge on possibilities of regulation of air flow/temperature regulation in different rooms **Want less:** – Reading of technical manuals.
Case 2 Norwegian passive house standard, Single family-houses, Freehold housing. Air-liquid heat pump serving hydronic floor heating. Balanced ventilation with heat recovery.	**Attitude:** – No major adjustments in terms of passive house promotion. The companies' sales department communicates information on housing for sale. The construction people did not know exactly what was communicated about passive house concept. **Type of information/offers:** – Prospect, drawings, price list, project description emphasising qualities, additional choices for up-grade of quality. **Reflections:** – Could improve training of sales personal. Visualisation and presentation could improve. Supplying information customers can and want to look into after buying. – There are unused opportunities to communicate more effectively, what the customer is buying. – Insufficient focus on information about passive houses. The sales people also do not have good enough knowledge on qualities and technical specifications. – The customers "were occupied with ordinary values such as location and plan layout. Even when we informed about qualities of passive houses buyers did not show interest". **First year after hand-over:** – Answered occupants' questions if they were contacted.	**Occupant experience:** – Little information in general during the purchasing process. **Want more:** – More on use of ventilation, regulation of air flow and temperature regulation in different rooms – General information about the passive house concept. – User-friendly and practical instructions – Proposition: User manual "for dummies" for understanding type of installation and use. Maybe a crash-course? **Want less:** – Technical manuals: "no one reads these anyway".

The table continues on the next page. →

Case number, Energy standard, Type of housing, Type of ownership, Information on heating- and ventilation system	**Housing developers: Information at hand-over**	**Occupants: Experience with information and information need**
Case 3 and case 8 (same housing developer) Norwegian passive house standard (case 3), low energy standard (case 8), Single family-houses, Freehold housing. **Case 3:** Air-liquid heat pump (for warm water), electric floor heating bathroom, wood-burning stove. **Case 8:** Air-liquid heat pump for warm water and hydronic floor heating, electric floor heating bathroom. **Both cases:** Balanced ventilation with heat recovery.	**Attitude:** – The housing developer has a countrywide routine for hand-overs, regardless of technical standard. The building manager is responsible for the hand-over procedure. – A general attitude is that they are responsible for the product as a whole. They do not want to involve the suppliers of technical installations in the hand-over procedure: "If we do not manage to communicate how to use the systems that we apply, our customers will not either". **Type of information/offers:** – Ventilation system is always explained. – The suppliers adjust the ventilation system before occupants move in. – The heating system: electric in single-family housing, simple user interface. In housing blocks heating system is a part of facility management, no users make general adjustments. – Hand-over is: one meeting to talk about the house and its use, one meeting to have the formalities signed. **Reflections:** – The technical manager states that despite having the same procedure there are "differences in customers experience that can be linked to building manager's ways and customers interests and needs". – The hand-over is usually satisfactory. **First year after hand-over:** – Customers make contact if they have questions. – Many wait until too long, e.g. until inspection after 1st year.	**Occupant experience:** – Varying experience at hand-over. – *"Enough information",* case 3 (passive house). – *"Too quick introduction",* case 8 (low energy house). – Report uncertainty on use of technical installations. **Want more:** – More information about the passive house concept – Different ways of presenting information Want less: – User manuals with technical descriptions
Case 4 Norwegian passive house standard and low energy, Semi-detached houses, Rented dwelling (Municipality owns). Air-liquid heat pump for hydronic heating and warm water, electric floor heating bathroom. Balanced ventilation with heat recovery.	**Attitude:** – The housing developer follows a common procedure for hand-over of all their buildings countrywide. **Type of information/offers:** – The occupants receive a user-, maintenance-, and operation manual. They explain the technical installations. – They usually invite the supplier of the heating system to demonstrate use. They explain the ventilation system themselves. – The impression is that owners are usually satisfied. **First year after hand-over:** – A general impression is that owners do not hesitate to get in touch if they have problems or questions.	– In this case, the Municipality rents out the dwellings. The technical division of the Municipality had good previous knowledge on the type of ventilation used. The developer is not sure about how the Municipality communicates information to the occupants. **Occupant experience:** – No information on ventilation and heating system received. The Municipality is still responsible for operation and maintenance of the technical systems in these houses. **Want more:** – To understand how to regulate temperature in different rooms – Clear information on who is responsible for what. **Want less:** –

The table continues on the next page. →

Case number, Energy standard, Type of housing, Type of ownership, Information on heating- and ventilation system	**Housing developers: Information at hand-over**	**Occupants: Experience with information and information need**
Case 5 Norwegian passive house standard, Row houses, Freehold housing. Solar collectors serving warm water and hydronic heating, supplemental electric heating. Balanced ventilation with heat recovery.	**Attitude:** – No specific information. **Type of information/offers:** – Short walk-through at hand-over – Information meeting with occupants and suppliers after moving in. – Information sheet with recommended settings. **Reflections:** – Procedure worked well for some but not for everybody. – The heating system is divided into zones, which seemed to be difficult to handle for some occupants **First year after hand-over:** – The occupants got in touch once problems or questions arose.	**Occupant experience:** – Varied experience. – Some are more interested in understanding and do well. Others practice trial and error. – Problems, error and adjustments were reasons why occupants switched off systems until these problems were solved – Could have used house and systems more efficiently if they had gotten better instructions. **Want more:** – More and improved presented information, especially on new types of systems (solar collectors). **Want less:** – User manuals with difficult technical descriptions.
Case 6 Norwegian passive house standard, Apartment block, Freehold housing. District-heating, 1 hydronic radiator, electric floor heating bathroom. Balanced ventilation with heat recovery.	**Attitude:** – They focus on user-friendly solutions already in the planning phase. Should be easy to maintain. – Customer service important **Type of information/offers:** – At hand-over, the occupants get a go-through with focus on use of dwelling (heating, ventilation, radiator, meters, use of sun shading, etc.). – In the handbook provided with user manuals, information is included on living in passive houses. – They have own customer service advisors. The advisors are trained by the suppliers, and they are trained in how to handle the customers' requests. **Reflections:** – The housing developer has received positive response regarding their hand-over procedure. – They want to improve customer service and work on web-solution (my pages) with visual /video information. **First year after hand-over:** – The occupants got in touch once there were problems or questions. – They have a net-chat solution to consult with occupants.	**Occupant experience:** – Most of the occupants were satisfied with the information received (handbook, go-through, information on passive house) – When there are problems, they contact the housing developer. Works usually well. **Want more:** – Some still want more information on ventilation system – Repeat information. **Want less:** –
Case 7 Norwegian passive house standard with solar cells, Single family-houses, Freehold housing Liquid-liquid heat pump, hydronic floor heating 1st floor, fan coil unit 2nd floor, PV warm water, Balanced ventilation with heat recovery.	**Attitude:** – No specific information. **Type of information/offers:** – Go-through at hand over – No concrete instructions, may be difficult to pass-on if dwelling is sold again – Occupants have to arrange themselves if they want to sign service agreements for the heat pump and for regularly exchange of ventilation filters. **Reflections:** – Occupants should have received more specific information, already during the building process – Appears that the occupants are hesitant to use the solutions applied: "They seem to be afraid to press the wrong buttons". **First year after hand-over:** – Occupants contact housing developer or suppliers.	**Occupant experience:** – Too little information provided. – Many technical user manuals, too short go-through. – Need more information and training in this type of dwelling (Photovoltaics). – Good help from suppliers, though they often had to find the answers themselves since solutions were new **Want more:** – Suggest: crash-course – Knowledge about the possibilities the applied systems offer – How to find and correct minor errors. **Want less:** – Thick, technical manuals.

> We have received enough information on ventilation and heating system; it is easy to find out how to adjust. Occupant, case 1.

Other occupants would have preferred more information and different type of information. Occupants appreciated the go-through procedures when held, however the quick nature of the go-through of new information had little long-lasting effects:

> The next day I wondered what they said and I had forgotten half of it. Occupant, case 6.

An occupant of case 5 tells the story from her perspective:

> If we had received more information, I believe we could have used the dwelling in a better way. We open the windows a lot to ventilate but I guess we could use the ventilation system more instead. It is a pity we did not learn more about the possibilities of the systems. We had a meeting with the housing developer. They stood in the kitchen and we quickly went through the operation of the different zones of the hydronic heating system. The technical description/manual is hard to understand. We got a short overview with numbers to press, but there is no explanation of the number's meaning.

Several of the interviewees asked for more user-friendly, more intuitive information in addition to/instead of thick and technical user manuals from the suppliers. Proposals were to make use of solutions such as apps and video instructions. These would be easier and faster to access to a broader group of customers than technical descriptions.

> There is a lot of unclear information. We would like a crash-course. That's what we recommend to the suppliers. We do not expect everything to be 100 % but one gets frustrated if you have to chase for all information yourself. Occupant, case 5.

The housing developer of case 6 had developed a strategic approach on customer service. Training of advisors, customer contact and service minded feedback are in focus. The occupants in this project were satisfied with the follow-up of the housing developer, even if in this project as well some occupants would prefer more training.

One occupant of case 6 said: "We received sufficient information on heating and ventilation. Adjustment possibilities are not very advanced". Several others in case 6 stated that the regulation of set-point temperature for the air heating is unclear to them. It is therefore sometimes used and other times adjusted but some do not know there is a possibility for adjustment.

Table 3. Calculated and measured energy consumption in total and for heating, in three cases with 13 dwellings.

kWh/(m² year) measured M and calculated C	Case 4		Case 5		Case 7	
	M	C	M	C	M	C
Total energy consumption	96	66	114	63	62	56
Energy consumption for heating	48	15	58	22	46	10

In several projects, the occupants regarded the heating system as easy to adjust. Once the heating system was a solution uncommon in Norway (where electric heating is typical), the need for information clearly increased. In cases where e.g. hydronic systems, PV, solar collectors were used, most occupants demanded better training and information. In addition, balanced ventilation in dwellings was mainly new to the occupants. The function and importance of ventilation in highly insulated dwellings is also not clearly understood in many cases. Practices adopted vary from not changing anything to daily adjustments. Earlier studies have also found that little understanding of operation corresponded with low opinions on e.g. ventilation solutions (Keul 2010; Schnieders & Hermelink 2006). When information was clarified the understanding and use of e.g. ventilation increased immediately (Schnieders & Hermelink 2006).

Overview of measurement results

The findings on measured energy consumption and indoor air temperature showed wide disparities among households and large differences in energy consumption within the same type of housing. The desired living room temperature for all the interviewed residents, except for one, was between 22 to 24 °C. The average measured temperature in the living room was 21,9 °C during the heating period and 23,6 °C during the summer. These are higher temperatures than commonly used as a basis for energy calculations. There was also a general desire to lower the temperature in the bedrooms. The desired temperature for the bedroom was in the range of 15 to 19 °C. The average measured temperature in the sleeping room during the heating season was 20,4 °C. It was experienced as a challenge to differentiate the temperature between different rooms in the home. Window airing was used to lower the temperature, especially in the bedroom and during the summer season. In cases where the desired comfort level was not reached by adjusting the heating or ventilation system or when the users did not experience sufficient control over the technical systems, the level of satisfaction was lower.

Calculated and measured energy consumption did not match in most cases. For the passive houses, an average energy consumption of 65 kWh/(m² BRA) was estimated. This is 23 % lower than the average of the measured energy consumption of 84,6 kWh/(m² BRA). The lowest measured total energy consumption among all passive houses was 54 kWh/(m² BRA) and the highest was 123 kWh/(m² BRA). In three cases the energy use for heating was measured in addition. Measurement results and calculations are shown in Table 3.

There were also large differences in the demand of energy for heating compared with calculations. The large differences are due to several reasons in our study. First, there were technical problems that had to be solved during the first year of occupancy. This clearly had an influence on the user's practices when the system was not working as desired, e.g. trough testing settings and switching and off systems. In some cases, additional heating devices were used. Secondly, the wish for high indoor temperatures in the living room will influence energy consumption for heating. At the same time, there is also the fact that window airing is often used to lower the temperature in bedrooms. If the doors to the bedroom are not closed, this will strongly influence energy consumption for space heating

for the rest of the dwelling. This is documented in e.g. Berge (2016). The measurement results are documented in detail in Thomsen, Gullbrekken, Grynning, Holme (pending).

Reflections and conclusions

The findings from the interviews indicated that the type of communication between the professionals and the occupants has an influence on how the occupants cope with the technical solutions in their new housing environment. In all cases, the occupants desired more user-friendly information. In case 6 where housing developer offered a more service minded system, users were in general satisfied. However, there is still room for improvement from the occupants' perspective. It is also difficult to link the way information has been provided to the results of the measurements. A general tendency is a higher consumption of total energy than anticipated, especially for heating. Through the interviews, it is possible to see that users were aware of a lack of information. For instance, case 5 and 7 had solutions that were uncommon to the occupants, such as PV, solar collectors and hydronic floor heating with zoning. In these cases, the occupants were least satisfied with the introduction they received. Especially in case 7 where there was no clear plan for occupant training and even the consultants stated that the occupants seemed to be afraid to press the wrong buttons. When conducting the interviews (after 9 months), the occupants felt that they had gained control. Overall, the level of frustration and trial and error could have been lower with another type of introduction.

A greater focus on the role of professionals for knowledge transfer, may contribute to reducing use-gaps in the first phase, and may also lead to better correspondence of energy related behaviour and consumption over a long-term period. The anticipated effect of more user-centred information on energy use is unfortunately not tested in this study. This remains a task for future research, e.g. a comparative study of different concepts of information, training and follow-up on use, operation, establishment of habits and effects on energy consumption in the first year and over longer periods.

When focusing on the professionals' role in establishing practices and influencing choices, it becomes obvious that the professionals have to be motivated to instruct the residents about how to use the house and the technical systems. As stated in the soft landings framework, the segregation of construction and operation phase is common and has negative effects on use and operation of new buildings (UBT & BSRIA 2009). The soft landing process addresses use and operation already in the planning process to provide a red thread all the way from procurement and planning, hand-over, and through long-term follow-up. In the light of the findings from this study and numerous previous ones, the procedure described above seems to be an approach to build upon. The findings also demonstrate how the users negotiate with the designer's script (Berker 2011). There is no evidence of "anti-scripts" (the opposite use than intended), but the intended script of the energy efficient housing is not necessarily followed correctly.

The question that remains is then how to increase motivation for knowledge transfer among professionals. Would incentives tied to energy performance contracts for professionals help to increase their interest in assisting occupants to operate and use the buildings systems correctly from the start? Different forms of energy performance contracts, or energy saving contracts, between the professionals and the residents could be a way of increasing the professionals' motivation and responsibility for the energy performance of the building on a longer time horizon.

Another thought one is left to ponder, is if housing is getting too complicated and too dependent on technical systems with the underlying assumption that occupants have access to the information they need and have an advanced understanding of the building. Is future housing then solely dependent on professional services to manage the technical systems in the dwelling? Or will the housing culture change and people in general manage complex systems in their dwelling in the future? And how to address the issue of elderly people and users with different expectation as a consequence of cultural heritage? In this light, occupant adjustment to future housing and its technical systems seems to be very dependent on the contractors' and professionals' ability to teach the residents about their dwelling.

Potential for improvement is then in the hand of the involved professionals. The outcomes of this study suggest the following measures:

- Improve user-friendliness of information: less purely technical manuals; but instead employ apps, video instructions, crash-courses, follow-up solutions (chat).
- Spend more time on explaining the systems in the building and transferring knowledge with the goal of establishing new user habits.
- Improve training of salespersons, adopting a more service-oriented approach in the housing developer industry and increase responsibility in follow-up process.

Last but not least: providing additional and more accessible information is a measure that may diminish energy performance gaps by better enabling occupants. But evidently, this is only one aspect of the energy consumption gap and there are other factors that must be accounted for, such as the increase in energy use to achieve higher comfort levels in new houses and other rebound effects that are not discussed in this paper.

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