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Users in low energy buildings: consequences for clients

Frédéric BOUGRAIN (CSTB) and Paula FEMENIAS (Chalmers University)

Abstract

The performance of low energy building relies not only on the quality of design, construction and operation but also on users' behaviour. To illustrate this situation, the study compares cases of low energy buildings in France and Sweden, countries with similar ambitions but following different policies to implement thermal regulations and evolving within distinctive contexts. The research indicates that there is a mismatch between predicted energy value and the real performance of the building. To limit this gap, there is a need to develop new relationships between clients, occupants and operators and to promote professional clients who can interpret users' needs without jeopardizing the energy performance of the building.

Keywords: user involvement, operation, design, low-energy buildings, client

1. Introduction

To mitigate climate change, most European countries have decided to reduce greenhouse gas emissions by a factor of 4 before 2050. The building industry, that takes the second largest share of greenhouse gas emissions in terms of energy end usage after transport, and has the highest share in the total energy use, is one of the main target. To deal with this challenge, various policies have been launched in Europe and standards have been issued to reduce the energy use in buildings. In countries such as France or Sweden, an increasing number of projects are oriented towards low energy buildings.

While both countries are affected by regional, national and European policy for energy efficiency in construction, there are also differences, which make a comparison interesting:

- Sweden has a large increase in reported low-energy construction last years and policy seems to be lacking behind practice. Conversely, France has been characterised as a country where state intervention is needed to guarantee the wealth and the strength of the economy. This is the case with the energy policy where several laws have been enacted and have contributed to the development of a new stringent thermal regulation.
- Sweden has a reputation of applying bottom up approaches to building design and planning. For example tenants' participation in public housing development and management is since long applied in Sweden (Bjerken, 1981) but more scarce in France.
- In Sweden, construction clients have the obligation to submit an inspection plan to verify the energy of the building. The client is in charge of the control of the maximum energy use defined by the regulation but the municipality can demand a verification and the client need to set up a monitoring system for energy. Similar obligation does not exist in France.

Conversely, in both countries, building energy use, as defined by the regulation, includes delivered energy for heating¹, air conditioning, hot water, operation of building services (pumps, fans, etc.) and other uses in the building (lighting in common areas elevators, etc.). Equally, in France and Sweden, the occupants' electricity use is not included in this definition (computers, copy machines, lighting, etc.). Consequently, users can have a great impact on the total yearly energy demand both with

¹ According to each national thermal regulation, in Sweden indoor air temperature for heating is 21°C while it is 19°C in France.

respect to 'building' related energy use such as heating and hot water as well as occupancy related electricity use.

The first objective of this research is to analyse how user behaviours are taken into account in the design and operation of low energy buildings. The second objective is to assess how users actually influence the energy performance. Indeed, users are frequently considered as responsible for the gap between expected and real energy consumption (Gram-Hanssen, 2013). Some recommendations will be drawn for clients who are responsible for shaping part of the framework of the construction process. Several taxonomies for construction clients have been proposed (Sexton et al., 2008; Tzortzopoulos et al., 2008). The research will only distinguish clients according to their level of experience with construction.

By following the aforementioned objectives, the paper will contribute to the research agenda established by the roadmap on "Clients and users in construction" (Haugbølle and Boyd, 2013). Among the objectives of the roadmap, one was "to assess different methods for involving users and stakeholders in decision-making processes on construction as well as operation of built facilities" and a second one aimed at understanding "the mechanisms behind successful/failed projects".

The first part examines the role of users and technology related to the operation of the building. The second part defines low energy buildings in France and Sweden. Then, two case studies focusing on the design, construction and operation of low-energy buildings, one school and one office, are presented. The paper is concluded by lessons and practical implications for clients.

2. The role of the user in energy consumption: a literature review

The large influence of user behaviour on the total energy use of buildings has been broadly reported in relation to housing (Gram-Hansen, 2013; Ingle et al, 2014) but also in relation to offices (Nguyen and Aiello, 2013). In their editorial of the special issue of *Building Research & Information* on "Housing occupancy feedback: linking behaviours and performance", Stevenson and Leaman remark: "even if the building fabric is robust and well insulated with suitable thermal mass, and the home has an efficient energy source, it will still be the inhabitant who ultimately determines how energy efficient a home will be" (2010, 440).

Brown and Cole (2009) identify two performance gaps in green buildings:

- The first gap concerns the predicted energy use and the real use of the building (the "credibility gap"). This is mainly due to the inability of designer to anticipate how people use the building in practice²
- The second gap relates to the spread between assumed and actual comfort. Three potential impact factors will challenge the "comfort/behavioural performance gap". First, practical/design relates to the complexity/simplicity of the building regarding readability, accessibility and feed-back from operation. Second, behavioural/situational factors concern the user's experiences, as well as knowledge and information provided. Finally, social /psychological causes address the individual sense of responsibility, awareness, expectations and social norms related to use. The potential impact of these three factors will be examined through the lenses of the academic literature.

2.1. The usability of the building and the responsiveness of the operator

Low energy buildings are frequently designed with a combination of passive and active systems. However, it has been stated as important to give the occupants control of the advanced and

² There is a huge literature on this issue. Interested readers could refer to De Wilde (2014) who presents a large and updated literature reviews on this performance gap.

innovative technical systems used to heat, cool and light the building (Hadi and Halfhide, 2010). Catarina and Illouz (2009) who analysed three certified office buildings (HQE – the French environmental assessment scheme), indicate that employees who were not able to monitor the light intensity forced the time switch. Thus lighting became permanent. Self-regulation makes occupants more sensitive and receptive to environmental messages. For example, Wagner et al. (2007) show that the occupants' control of the indoor temperature and the perceived effect of their possible different interventions influence their degree of satisfaction. Many examples show that when technical solutions generate discomfort, they generate counterproductive reactions of users. Thomsen et al. (2005) examined twelve experimental projects (low energy consumption buildings with solar installations) and reported that in some cases the noise due to the ventilation system has led occupants to block the air supply system.

According to Catarina and Illouz (2009), technology should not be a goal but a tool at the service of easier operation and better performance. *"Keep the design simple. Automation is not always the answer"* (Hadi and Halfhide, 2010, 63). Comparing the energy consumption of three retrofitted building, Galvin (2014) noticed that complex technologies encountered some technical errors. Moreover, due to the complexity, occupants had difficulties to control the heating. Moreover, complex technical systems require more maintenance and the associated costs do not always compensate the energy saved (Branco et al, 2002).

Finally, the quality of service provided to the occupants (appropriate temperature, reliable technical systems, and trust in the relationship with the facility manager...) strongly influences the behaviours of the occupants (Catarina and Illouz, 2009). Dissatisfied occupants tend to modify the fine tuning of equipment. Thus, the reliability of technical systems becomes the prerequisites to the appropriate behaviour of the occupants.

2.2. Users' expectations and need of information

The user's understanding of the building and their active involvement in the operation is of high importance to achieve energy goals. Information and instructions to users as well as to the operating personnel is thus paramount. Leaman and Bordass (2007) state that users of green building are more tolerant to deficiencies and discomfort if they know how the building is supposed to work. There are studies indicating the importance of also repeated campaigns to inform users and operators as these may change over time resulting in increasing energy use over time.

Several studies report that it is often the case that either occupants or operators are trained to understand how buildings work. New systems are rarely presented to the occupants. Due to lack of communication, the occupant tends to judge negatively the systems installed since they have a bad understanding of how to use them (Catarina and Illouz, 2009). In twelve projects examined by Thomsen et al. (2005), users complained as they did not receive instructions on how the systems and the building physics work. Moving to a "green building" is frequently a managerial decision and employees are frequently forgotten (Catarina and Illouz, 2009). Once people have moved, it appears that communication should be done in two steps. First, occupants have to be informed about the specificities of the building when they move. A second communication campaign has to be organised at least six months after moving in, when occupants are more aware of their living environment (CSTB, 2007).

"Thus it is important to ensure adequate and appropriate training for all building occupants. It is important that occupant understand not just how to control the building but why they are being asked to control it in a specific way that might be counter-intuitive" (Hadi and Halfhide, 2010, 63).

However, the interplay between user and building in order to reach energy goals is complex and related to the social context of both production and use. Paula and Taylor (2008) found that the

attitudes and preferences of the users, such as whether they can identify with the concept of the energy-efficient building, will also be important for the overall satisfaction.

2.3. Awareness and individual sense of responsibility

Higher energy efficiency in buildings can paradoxically increase the energy use as occupants value their comfort in the first place. Occupants tend to adjust their behaviour to the efficiency of the building in which they are living. Consequently, energy savings are seldom as large as predicted by the dynamic simulations in the design phase (Gram-Hanssen, 2014). *“The potential ‘energy savings’ from improved energy efficiency are commonly estimated using basic physical principles and engineering models. However, the energy savings that are realised in practice generally fall short of these engineering estimates. One explanation is that improvements in energy efficiency encourage greater use of the services (for example heat or mobility) which energy helps to provide. Behavioural responses such as these have come to be known as the energy efficiency “rebound effect” (Sorrell, 2007, VII).*

This rebound effect is also associated to a lack of sense of responsibility. ENERTECH (2012) criticised occupants who open windows during the winter without turning off the heater and who heat above 23°C in order to be able to wear only a tee-shirt while indoors both in winter and summer. Galwin (2013) noticed that a relatively small percentage of consumers (23% of households) consumed 52% of the space heating energy. Dard (1986) considered that these behaviours are the result of hygienist speech as the opening of windows was considered as very healthy in earlier time. Such, collective ‘practices’ that can be culturally based has been found important to discuss in order to address more energy saving behaviour (Gram-Hanssen, 2013).

It also appears that during the first year of operation, systems rarely work as expected and they need to be adjusted to the use (new buildings need to dry out which demand extra heating). Indeed, building systems generally operate according to occupancy assumptions. However, experience shows that the real occupancy in office buildings is much lower than the planned occupancy (Klein et al., 2011). Thus, it requires at least one year to optimise the energy systems according to the real occupancy and users’ expectations. Moreover, technical disorders are frequently more numerous during the first year. This is also due to the lack of involvement of operators during design and construction phases. Since people moving from a conventional to a green building have usually high expectations of how the building would perform, any technical disorder will be counterproductive and will rapidly demotivate occupants (Catarina and Illouz, 2009) and increase the gap between expected and real energy consumption, especially for innovative low energy buildings.

3. Methodological considerations

The main goal for the research has been to learn about how behaviour of users is taken into account during the design of low-energy buildings and in what way the users will influence the results. The studied phenomenon is a rich of information, context-dependent and rather unexplored as a problem. Although the participation of users in planning and design has been set forward as one important foundation for sustainable development of the built environment (Kaatz, et al, 2005), the influence on the performance through user involvement in the design of energy efficient buildings seem to be little studied. Higher levels of user participation to improve development (and dissemination) of sustainable energy technologies have been studied in single cases of user-led innovation (Ornetzeder and Rohrer, 2006). The problems experienced in the delivery of a complex sustainable building as a result of not having involved the operation staff and users in the design has also been observed (Femenías, 2006). Accordingly, in-depth studies seemed necessary to further explore the problem. Qualitative case study methodology was considered the most appropriate mean to get close to the study objects (Flyvbjerg 2006). The objective is not to predict or generalise but to describe and understand.

Considering the aim of getting as much information as possible out of the case studies, the strategic choice of cases is of high importance. As stated by Flyvbjerg (2006) a critical case of the studied phenomenon will provide more information than a representative or randomly selected case. A case (Ragin 1992) in this study, is the design, construction and operation of a low-energy building for public purpose. Cases with outspoken ambitions of producing low-energy buildings were deliberately chosen since they represented 'most likely' outcomes of the case in the two countries. Furthermore, data and feed-back from the building in operation were needed. Thus, selected buildings have already been in operation for at least one to two years. In France, the market of low-energy buildings has emerged in the latter years and the case is consequently a pioneering example. In Sweden, the development of low-energy construction has come further and a case was chosen among a larger selection of possible cases representing a client that has taken the step from pilot project to implementing low-energy construction as a standard. A third criterion was the willingness of the project owners to share information and data. The selected clients have had the ambition to learn from the pioneering projects and invited research to take part of and support their learning process.

Regarding data collection, the case studies are based on documents from the projects, energy data, and face-to-face interviews with key actors. The interviews focused on the organisation of the projects, their origins and goals (mainly energy and environmental issues), the characteristics and impacts of main innovative solutions on the operating costs, the competencies of the different stakeholders of the projects, the nature of the contractual agreements, the responsibilities in case of poor performance, the performance of the building in operation and users' involvement during design / construction / operation.

For the French case interviews were carried out between June and September 2013 with: representatives from the client (IGN); the architect, the thermal designer, the environmental consultant, the operator, and the two people in charge of following the contracts and supervising the operator representing the users of IGN (client and user) and METEO France (user). All respondents received a case report in French and were able to send their comments to the authors. Two external reports completed after 12 and 18 months of operation by a consultant assisting the client during the first two years of operation, were important complementary sources of information. These reports aimed at checking whether energy goals were reached and providing feedbacks on technical solutions implemented in the building.

Interviews for the Swedish case study were carried out between 2012 and 2014 with: four representatives from the client, the architect, the HVAC engineer, two representatives from the main contractor and two technicians from the operational unit of the client organisation. In addition, four users were interviewed: the present Headmaster, one teacher and two porters. Besides documents from the process an earlier report focusing on energy measuring were also sources of information.

A first paper based on the same cases has already been developed (Bougrain and Femenias, 2014). This first research examined how energy objectives have modified the balance of power within the construction business system in France and Sweden.

4. Low energy buildings

The meaning of the term "low-energy building" is different from one country to the other and has changed over time with technological progress and the evolution of national thermal requirements. According to the European project Build with CaRe (Tofield, 2012, p.6), "*a low-energy new building is a building that is designed to achieve or to come close to the passivhaus standard and one where passivhaus or similar quality processes are followed to ensure that design energy use is realised in practice without compromising occupant comfort and satisfaction*". The European directive on the energy performance of buildings even moved forward and defined "nearly zero-energy building" which are well insulated buildings with good airtightness and renewable energy supply on the

building (European Parliament, 2010). Low energy buildings are frequently associated with labels such as PASSIVHAUS in Germany, MINERGIE in Switzerland, and ENERGY STAR in the United States. Product labeling is one way to go further than normal practice and to reduce information asymmetry between owners and buyers / users. The cases of France and Sweden illustrate how low energy standards between countries may differ.

4.1. France

Various policies have been launched by the French government to deal with the environmental challenge. Lots of standards have been set up since the oil crisis and the mid 70's to reduce energy consumption in buildings. In 2007, a label given to low energy building was created. It was inspired by the Swiss label MINERGIE. According to this label, the annual requirement for heating, hot water, lighting, air conditioning and all the pumps required to provide the building energy needs, must be lower than about 50 kWh/m²/year (primary energy). Indeed, this value is multiplied by a coefficient depending on climate area and altitude. It means that the consumption value can vary between 40 kWh/m²/year on the Mediterranean coast and 65 kWh/m²/year in the East and North of France.³At the end of December 2012, this label became the reference for the new thermal regulation (RT2012). The target for 2020 is “nearly zero-energy building” to conform to the European Directive. At a local level, regulation is sometimes more stringent. For example, in Paris the maximum primary energy consumption for new-build operations is 50kWh/m²/year and exceeds the national standard for this part of the country (65 kWh/m²/year).

4.2. Sweden

Sweden has had requirements on insulation of exterior walls in new constructions since the 1950s. The building energy regulation was strengthened in the wake of the 1970s energy crises but without further substantial updates during several decades. Since 2006, the Swedish energy regulations for new construction have been increasingly strengthened. The last up-dates came into legal force in March 2015.

At present the building regulation demands a maximum of 70 kWh/m²/year (delivered energy) for multi-residential housing and 60 kWh/m²/year for non-domestic buildings in the Southern climate zone IV (northern climate zones III, II and I add on 10, 30 and 45 kWh/m² respectively). If electricity is used as heating source the maximum energy use is 45 to 85 kWh/m²/year. The construction client has the obligation to provide an energy calculation before the construction.

Last years, Sweden has seen a rapid development of low-energy construction. In 2010, 24% of all new multi-residential construction in Western Sweden was considered as low-energy buildings i.e. having an energy performance of 25% less energy use than required by the building regulation (Wahlström et al, 2011). This progress has not been pushed by national regulation but rather by commitment among progressive clients and local environmental policy in larger Swedish cities which have had specific demand for low energy construction (often around 60 kWh/m²/year which was 33% lower than the building regulation at the time). Upcoming European demand for near-zero energy building is a contributing factor pushing for innovation in the field of low-energy construction.

³ A first feedback study based on 17 low energy buildings (offices and housing) indicated that performance were lower than expected because information about the occupancy and the use of the buildings were imprecise at the design stage, technical systems were underperforming and facility management was poor (CEREMA, 2015).

5. The French case

5.1. Characteristics of the project

The construction of the new headquarters of IGN (National Geographic Institute) and METEO France, and a Parisian antenna for SHOM (Hydrographic and Oceanographic Service of the Navy) was decided in 2007 by the Ministry of Ecology, Housing and Transport. The aim was to gather in one place services formerly located in Paris and its suburbs. The Ministry was the client. However, the supervision of the project was delegated to a regional division. Traditional public procurement which is regulated by the law n°85.704 laid down the 12th of July 1985, was used and led to separate tenders for construction works and maintenance/operation.

When the Ministry launched the contest to select the architect, the building was not supposed to be certified for sustainability or a low energy building. However, a national multi-party debate on the environmental policy modified the Ministry's ambitions. During the auditions in the procurement process, the client asked the design team who was finally selected, to slightly modify the project in order to certify the building according to HQE (High Environmental Quality), which is a French environmental assessment system, and to get the label "low energy building". The HQE certification relates to the operation management system and the environmental quality of the building. Before this project, the client (the Ministry) did not have any experience with low energy building.

The cost of the building works reached 30 million Euros for a total area of 14 900 m² (and 180 parking places). The building hosts about 620 people.

5.2. The integration of the user needs at the design phase

The users were not involved during the design process. The people in charge of the facility management at METEO France and IGN discussed the access control, electrical current and transfer of professional equipment together with the architect at the design stage. They also sent proposals to the architect regarding furniture and materials in the entrance hall. However, the architect did not take their suggestions into account.

Several technical and architectural decisions have come to have a strong impact on the use. For example, the environmental consultant to the client, optimised the size of the windows in order to find the right balance between daylight and thermal supply. Consequently, all offices and all meeting rooms benefit from natural lighting. Moreover, there are sensors that monitor the light intensity in order to control the artificial lighting.

Some proposed solutions were refused by the client who thought that these could lead to dissatisfaction among the users. For example, the environmental consultant wanted to promote natural ventilation. However, the client considered that such a solution would not have been adapted to the summer climate. Moreover, a natural ventilation system would have required the use of a mechanical system to open the window for night ventilation, which would have increased construction and operation costs.

5.3. The role of the users during the operation of the building

A private facility manager/operator maintains the building and monitors the energy use. This facility manager was involved after the delivery of the building. The contract was signed for one year and it can be extended three times. The client wanted to launch a tender for an energy saving performance contract. However, IGN who monitors the facility manager considered that it was too early since the building was new and did not have any record for energy consumption.

Users report issues to an onsite helpdesk which is the interface between the users and the facility manager. It also allows for records of response times and data on the pattern of operational errors.

Once the users inform the helpdesk, the facility manager has to satisfy the demand within a certain time limit which depends on the significance of the part of the building concerned. This approach was new for people working at METEO France who had never recorded and formalised maintenance activities before moving. Consequently, a specific organisation was developed to conform to the characteristics of the assistance process. Sometimes, urgent matters are recorded after being solved in order to keep record on the problem and its solution.

5.4. Occupancy and energy consumptions

After one year of operation, energy consumptions are much higher than expected (table 1). This was due to the dysfunctions of some technical systems (e.g. the geothermal) and a gap between the theoretical energy value and real use of the building.

Among the explanations, the failure for the program of the building partly explains the gap between theory and reality:

- One floor dedicated to METEO France is in operation 24/7 while the air processing system was supposed to work only five days a week from 8 am to 7 pm. Since the seven floors are inter-dependant, the air processing system is in operation 24/7.
- The entrance hall was supposed to be heated at 17°C. This temperature is fine for employees who cross the hall but not for receptionists who work there. The architect had refused to build a specific 'box' for receptionists since this would have interfered with her visions. Instead, heaters were installed above the receptionists and also at the sides of the entrance itself. As a result, most of the energy used to heat the building is used in the entrance hall.

Table 1: Comparison between energy objectives and consumptions in operation

Uses	Objectives (kWh/year/m ²)	Consumptions in operation (kWh/year/m ²) 05/12 – 04/13	Consumptions in operation (kWh/year/m ²) 11/12 – 10/13	Gap for the last period
Heating	3.78	21.95	24.81	+ 555,15%
Air conditioning	4.27	19.26	20.72	+383.83%
Hot water	0.19	-	-	-
Lighting, office automation	38.48	49.88	48.98	+27.27%
Ventilation and auxiliaries	4.48	11.83	11.72	+160.87%
Total without PV	51.20	102.93	106.24	+107.30%
Photovoltaic	1.20	0,81	1.05	-11.18%
Total	50	102.12	105.19	+110.11%

Source: BEHI (2013)

5.5. Users satisfaction and communication during operation

During the first year, the temperatures were not even from one floor to the other. According to a report ordered by the client, temperatures on the 22nd of April, at noon ranged from 21.6°C at the ground floor to 24°C at the seventh floor. At this time, the centralised control station was not yet adjusted. The responsiveness of the operator was limited because when he was appointed, the acceptance of the centralised control station was not done by the client. Thus, for about five months, the operator did not modify the parameters in order to avoid involving his liability.

According to a post occupancy survey ordered by the client, about 42% of the respondents experienced cold during the first year.⁴ At the same time, 28% reported that they opened their window during the winter. 27 people indicated that they brought their own heater to their office⁵. According to the logistics manager at IGN, this behaviour disturbed the balance of the heating system. Users were also critical as they only are allowed to increase/decrease the temperature of their office by one degree. The control system is experienced as not being reactive enough, which can be explained by the high thermal inertia of the building. Among the 108 respondents who tried to modify the temperature of their office, only 21% were satisfied. According to the operator, the high thermal inertia makes the management of the building complex during spring and fall. During these seasons, there is a need to heat the building early in the morning, which might lead to over-heating in the afternoon instead.

According to the survey, the users appreciated the natural lighting of the meeting rooms and their office. However, they were very critical about their inability to modify the intensity of the light of their office which is monitored by sensors. During mid-seasons, despite window shutters, some users were disturbed by the sun that reflected onto the screens of the computers. According to the architect, this problem could have been avoided if the users had followed her layout for each office.

METEO France provided their/the employees with a welcome booklet. Moreover, during the first three months posters were displayed in the corridors in order to explain to the principles of the building in operation (e.g. lighting controlled with sensors, the role of the thermostat in every office...).

IGN developed a similar approach. A message was sent to the users about the building in operation. It mainly concerned the heating and lighting systems (whose intensity varies with the external brightness). Nevertheless, according to the satisfaction survey, this information was not sufficient. 84% of the interviewed occupants (257 over 306) claimed that they were not trained and that they did not receive any explanatory note on how and why to control the building in a specific way.

5.6. Conclusion from the French case

The French case illustrates the “credibility gap” (a mismatch between prediction and measurements) put forward by Brown and Cole (2009). It results from the poor links between users, client and the design team. During the operation of the building this situation is not compensated by the relationship between users and facility managers and a communication plan that would modify the behaviour of the occupants.

6. The Swedish case

6.1. Characteristics of the project

The Brottkärr project is the addition of a new annex and the refurbishment of an existing building to host a pre-school and a school for children (up to 10-12 years), in total 300 children occupy the facilities. The total area is 3600 m². The building is in use since August 2011. A 2 year guaranty follow-up was completed in August 2013. The building is heated with a geothermal system and balanced ventilation system with heat recovery and CO₂ steering. The building design is also adapted to low-energy use with temperature zones, a compact form and thermal inertia.

The client, a municipal agency, owns and operates facilities for the city of Göteborg. Their property includes pre-schools, schools, housing for elderly and housing for people with special needs. Since 2011, the agency has an owner directive to only construct low-energy buildings, defined by 45

⁴ This survey was done by a student in June 2013. About half of the occupants answered (306 over 620). Among the 306 people who answered, 172 worked at METEO France, 126 at IGN and 8 at SHOM.

⁵ During the first winter, temperatures were apparently around 19°C in the morning at the ground floor.

kWh/m² and year in delivered energy. By the time of the design this was 45% lower than the regulation that dictates 80kWh/m²/year for non-domestic buildings. During 2013, the agency delivered over 20 low-energy buildings, mainly schools and nurseries.

6.2. The integration of the user needs at the design phase

The architect and the engineers appointed for the design did not have any problems to theoretically reach the energy objective. During the design process, the client demanded energy balance calculation at several occasions. Depending on the method used the consultants reached different results (Table 2).

The Headmaster and some employees from the school, representing the users, were invited to take part in the design process, if their working tasks permitted. There was no specific time allocated for the future users to take an active part in the project. During the construction phase, the Headmaster was changed twice. This represents a discontinuity for the user involvement in the delivery of the new facility. Furthermore, there was little documentation from the earlier stages of the process that could be communicated to the new participants. In fact, the involvement of the new Headmaster, who entered late in the process, mainly consisted of getting continuous information about the progress of the construction work. On the whole, the users find their involvement to be limited to the approval of the ready design and drawings.

6.3. The role of the users during the operation of the building

In order to reach an optimal performance of the low-energy system there are automated systems which are not dependent on the active user involvement. There are sensors to regulate lighting, heating and ventilation, and according to a representative from the project side, these should not be altered either by the user or the operational staff.

The operating technicians have had initial problems with the building and many adjustments have been needed after delivery. The technicians say that they were not informed that this was a low-energy building. The technicians have not received any special training or information about the systems. However, low-energy buildings do usually not involve technologies that are totally unknown to the technicians. A more general problem lies in the small amount of time that the technicians are given to operate and manage buildings. The technician responsible for the operation of the school has since the delivery changed his employment due to a very high workload. He was alone responsible for 170 facilities and operated more than 300.000 square metres.

One technician says that the project division at the client focuses on new solutions without considering the effect for the operation. He would like to be more involved in early stages of the design process, but normally there is no time for this. A quote from the technician says: *“As project leader, you want to do something that catches the eye, test new stuff. And the ones who are affected are the operating technicians. It is difficult to get balance in the technical systems.”*

6.4. Occupancy and energy consumptions

The energy use of the school building is higher than expected. The client, the municipal agency has the same experience in several of their low-energy facilities and has initiated a project, with Brottkärr School as a case, to develop methods for the continuous control of energy goals through the whole process from design to use.

Moreover, the client experiences a lack of available data on user behaviour for schools and other kinds of special buildings. The agency has the ambition to define in-data and they have also developed their own calculation method which they find better reflect reality than the calculation method proposed by the Swedish building regulation.

The two year guarantee control indicated that the building did not function as planned. Then, the client ordered a follow-up by an external consultant which also served a more general purpose of advancing their knowledge in low-energy construction. There have been some problems with the monitoring of energy use and not all separate energy flows have been measured (Table 2). Preliminary results from the follow indicate that the energy gain from internal heat sources and from passive solar energy were overestimated. In addition, the indoor temperature is suspected to be higher than the calculated 20 degrees. Furthermore, electricity for fans, pumps etc. exceeds the calculated and the operational time for the fans has been underestimated. The users are suspected to interfere with the system. The entrance doors are heavy in order to shut quickly when opened. However, the users tend to leave the doors open during recreation as the original automatic door openers were quickly worn out.

Table 2: Calculated and measured values for Brottkärr School⁶

	Goal kWh/m ² / year 3475 m ²	2010 - Case 1 calculation (Client's own method) kWh/m ² /year 3475 m ²	2010 - Case 2 calculation (according to regulation) kWh/m ² /year 3475 m ²	2013 - Real energy use kWh/m ² /year 3475 m ²
Heating need ¹	-	104	103	No data
Heat gain/heat recovery ²	-	-67	-74	No data
Total heating need	19	37	29	25,5
Electricity for operation of building	16	6	17 ³	10 19 (incl. HP)
Delivered energy from heat pump			-34	No data
Specific energy need	45	43	12	35,5 44,5 (incl. HP)
Electricity for users activities	-	9	9	21 (deduced not measured)
Total electricity need	-	15	26	40

¹ Including transmission and ventilation losses, losses in systems, and hot water

² Heat gain from insolation, internal heat sources and heat recovery

³ Including 11 kWh/m² and year for the heat pump

6.5 User satisfaction and communication during operation

The teaching staff is rather disappointed with the building, with the heating and the ventilation systems, but also with some functional aspects. Their disappointment can be traced back to their limited influence on the design but also on communication problems with the facility manager.

The users as the operation technicians reports that they were not informed about the low-energy profile or in what way this would affect the use of the building. The users are dissatisfied with the fact that they cannot adjust the heating or the ventilation. During the night and in week-ends the heating and ventilation is automatically lowered to a minimum resulting in temperatures of 14 degrees when school starts on Monday morning, and also in bad air quality.

The extreme air-tightness also results in over heating, especially on sunny days. The ventilation system is pre-installed to start when temperatures raises and the users have experienced temperatures of 23-26 degrees in the classrooms, which they consider too high. Sun-shading that

⁶ Since 2010 the client use two parallel models for energy balance calculations Case 1 based on their own method and in-data and Case 2 according to a method proposed by the building regulations.

should be installed has been omitted and the blinds have quickly been worn and deteriorated due to frequent un-programmed use.

6.6 Conclusions from the Swedish case

In the Swedish case, it is the same municipal agency having the role of client and taking care of the operation and facilities management. Still, there are problems to link the design to the operation and use. The agency has reacted on complains among the technicians and has since the case study was made employed more staff for operating their facilities.

The Swedish case shows problems with integrating users and behavior in the design phase. There is a lack of collected information on user habits to be used as data in calculations. The users are involved to take part of the design process, however their participation has been limited due to lack of time, knowledge and discontinuity in the process as the user representatives were changed during the project.

7. Discussion and lessons

The comparison between the French and the Swedish cases points to most issues identified by Brown and Cole (2009):

Cases firstly illustrate the credibility gap (the mismatch between predicted energy value and the real performance of the buildings). In both cases, it results from the inability of the designers to integrate the future behaviour of the future occupants. However, when they are invited to take part to some meetings, occupants are also unable to anticipate their future working environment. Thus, there is a need in such a situation to rely on professional clients or to involve intermediaries representing occupants.

The gap in experience between the French and the Swedish client, speaks in favour of agencies that procure, own and operate public buildings and are in charge of planning and managing large property projects, and act as professional clients. Inexperienced purchasers of construction services with a limited expertise in procurement process such as the French client frequently lead to a poor performance of buildings.

“Lead clients” are ready to modify the frontier between design, construction, operation and use stages. They are professional and can clarify and interpret users’ needs, establish a hierarchy among them and propose an occupier brief which is a compromise between the users’ expectations and the energy constraints. In this case, the involvement of the users at the design stage is not required. However, client needs to involve operators at this level since they cannot speak for operators.

Table 3: Impact of client professionalism on the relationship with occupants and operators at different stages of a project

	<i>Design stage</i>		<i>Operation stage</i>	
	<i>Professional client</i>	<i>Unsophisticated client</i>	<i>Professional client</i>	<i>Unsophisticated client</i>
<i>Occupants / intermediaries representing occupants</i>		<i>Coproduction</i>	<i>Information / participation</i>	<i>Information / participation</i>
<i>Operators</i>	<i>Consultation / Cooperation</i>	<i>Coproduction</i>	<i>Cooperation</i>	<i>Coproduction</i>

Unsophisticated clients need to develop stronger relationships with both future occupants and operators. To compensate their lack of experience, they would need to find intermediaries (architects, designers, consultants...) who would identify and interpret the needs of the users and integrate the requirements of the operators at the design stage. The aim would be to coproduce the occupier brief, which focused on design issues and described the required functionality of the facility in technical and “usable” terms, with the identified stakeholders. Table 3 summarises those relationships between clients and the other stakeholders of a building project at the design and operation stages.

Cases also concern the usability of the building and the responsiveness of the operator:

The cases show the growing use of automatic systems regulating heating, hot water, air-conditioning and lighting. Everything is made to reach an optimal performance of the low-energy system. This approach aims at reducing the users’ ability to dramatically influence the energy use. This situation could be counterbalanced by a closer relationship between the occupants and the operator. In the French case, users report problems to an onsite helpdesk which is the interface between the users and the facility manager. It also allows for records of response times and data on the pattern of operational errors. However, the responsiveness of the operator regarding complaints about the temperatures was bad. Similarly, in the Swedish case, users were dissatisfied since they were not able to adjust the heating or the ventilation. The dry in-coming air even led to health issues. Moreover, users reported communication problems with the facility managers. In both cases, the operator was more a contractor than a partner. In France, he was selected after the handover. Moreover, he signed a one year contract which can be extended three times. In Sweden, the technician responsible for the operation of the school belonged to the same organisation as the client. However, he did not feel concerned about the project. He was also alone responsible for operating in total 170 facilities. Due to his high work load, he finally resigned.

The second lesson would thus be that the development of automatic systems needs to be counterbalanced by the development of new relationships between occupants and operators. There is a need to consider the operator as a partner not only for the client but also for the occupants. Mid to long term contracts are necessary to provide operators with incentives to regulate the building on the long run and to develop relationships based on trust with the users.

The third issue has to do with the need to inform the users of the buildings. The literature emphasises on the importance of informing and activating the user in order to counteract their behaviour. In both cases, occupants received little information about their building. When it was done, users were not familiar with their work environment and they had no questions about surrounding systems and equipment. This situation cannot raise the awareness and the sense of responsibility of users (one of the issue identified by Brown and Cole). There is even a risk on the long run to develop counterproductive situation that would demotivate occupants and reinforce the rebound effect.

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