THE DEVIL IN THE DETAIL - THE STORY OF A SUSTAINABLE TRAIL BLAZER

Christian Koch\(^1\) and Niels Haldor Bertelsen\(^2\)

\(^1\)Aarhus University, Herning, Denmark
\(^2\)Danish Building Research Institute, Aalborg University, Denmark

The climate change agenda have yet again put construction under pressure. Not only is the industry expected to deliver value for the customer, cost reductions, and efficiency but also sustainable building of all types. This paper reports of a trail blazing building of a dormitory in Central Denmark in, 2006-2009. The project was supposed to be at a time delivering value, lean design and prefabrication. Moreover it was supposed to, and did indeed become, certified as a passive house following German standards. Using theories of innovation of both sociological and business economic origin, the paper discusses how early movers of innovation tend to struggle with image problems and even get discredited, because of “minor details”. The empirical work was carried out by one of the authors (Bertelsen, 2010). It encompasses both an evaluation of the design and construction process as well as a post occupancy evaluation. Process experiences encompass the use of a multidisciplinary competence group and performance measurement. After a creative beginning the process was forced into more traditional controlling, driven by challenges such as the necessity of a German pre fab supplier, the local craft contractors and the economic goals. Energy calculations, indoor climate and issues around demands of square meters became problematic. The quality goal, to obtain a passive house certification reigned over realizing a good indoor climate including sufficient heating. Project management needs to handle quantitative complexity. As the project manager noted: “Because it is damn important to remember the banalities, when we built”.

Keywords: demonstration projects, Denmark, passive houses, prefabrication.

INTRODUCTION

As zero carbon housing moves from vision to articulated and regulated goals for the economies, challenges of commercialization of this types of sustainable buildings becomes prevalent. Especially the price/value balance and the performance of sustainable housing come into the centre of the needed innovation and product development in response to climate change. In a Danish context some sustainable housing types have received the reputation of being too expensive and not living up to clients expectations in terms of performance of the building, measured in for example indoor climate (Isover, 2010; Larsen and Brunsgaard, 2010). Isover (2010) thus finds that a small sample of passive houses realized in Denmark, are 6-12 % more expensive than comparable traditional housing and Larsen and Brunsgaard (2010) find a series of heating and cooling issues notified by occupants in the passive houses.

Moreover even if sustainable bungalows are gradually becoming closer to a commercial market, other types of sustainable buildings, such as office buildings and

\(^1\)christian@hih.au.dk

institutional buildings are less widespread. A number of dynamics therefore leads to the exercising of demonstration projects and other attempts to market and brand sustainable buildings, their efficiency and blazing the trail for more projects.

This article therefore aims at analyzing a demonstration project as part of the commercialization of design and of the innovation process. The specific demonstration project was realizing a dormitory from 2006-2009 and encompassed designing four sustainable buildings of 66 rooms for students according to German norms of passive houses, at a reasonable price/value.

The article adopts innovation theory (Brown and Hendry, 2009), conceptualizing the role of demonstration projects and fields trials as main theoretical position. This is combined with science technology and society elements (represented by Schot and Geels, 2008) and more experientially based evaluations of demonstration projects (Clausen, 2002 Smyth, 2008). These combined perspectives contribute to look at commercialisation through demonstration projects as a particular important phase of carrying out innovation in construction. Demonstration project are often assumed to be of technical trial type and the commercialisation is overlooked. Moreover in a construction context process trials are equally important.

The article follows a classical structure; method, theory, empirical description, results and discussion and conclusions.

**METHOD**

Demonstration projects are a frequently used mechanism in government funded development efforts. Yet it is an underconceptualised research object. Brown and Hendry innovation theory oriented conceptualization is used here, with modification addressing construction sector characteristics (Clausen, 2002 Smyth, 2010).

Empirically, one author (Bertelsen) followed the process as an evaluator from April, 2007 and mapped the previous process (the project started in March, 2006). Process evaluations from 14 competence group meetings were generated as well as a post project meeting in August 2008 (Bertelsen, 2010).

In 2010, after one year of occupation, the occupants were asked about their evaluation through circulation of a short questionnaire of 16 questions using the five step scale. 18 occupants out of about 70 possible responded. Using questionnaires with occupants also involves attracting and mediating a communication between tenants and owner on minor issues for improvement. The open commentary field of the questionnaire seems to have attracted that.

The paper is not analyzing the broader effects of the demonstration project, i.e. the sector or company learning of this project. Other findings (Smyth, 2010, Clausen, 2002) have shown poor dissemination effects of learning and concepts from demonstration projects, but the question is not dealt with here. The site experiences are only marginally treated. Moreover the paper refrains from the issue of the design of possible public incentives to improve the commercialization.

**THEORY**

Commercialisation of a product involves some kind of interaction with future users and end customers. Demonstration projects can be understood as ‘important attempts to shorten the time within which a specific technology makes its way from development and prototype to widespread availability and adoption by industrial and commercial users’ (Lefevre, 1984), and Brown and Hendry (2009:2560) defines...
demonstration projects as ‘all those activities that expose the technology to realistic user environments and are partially funded by the government with the intention of testing its suitability for more extensive diffusion’. Business economists have for long observed that commercialization of a product involves a learning curve, in which producers, suppliers and customers gradually modify the product and its related processes (Brown and Hendry, 2009). On this background Brown and Hendry claims that there is a demonstrated relationship between growth in installations of a new product and a reduction in cost resulting from gradually obtaining economies of scale (Wene, 2000), even if the relationship between development of installations and reduction of costs also varies. Nevertheless the mechanism is often referred to when establishing demonstration projects. In a classical definition Baer et al. (1976,1), defined a demonstration project as ‘the final stage of scaling up’, underlining the element of possible future repetition and more customers involved or to be involved. In a construction context, projects supposed to deliver finished buildings are often used as vehicles for field trials and demonstrations (Clausen, 2002). The options of “scaling up” would be related to industrialization strategies as our case below analyse.

Brown and Hendry (2009) discuss the learning effects related to demonstration projects in terms of three aspects (Brown and Hendry, 2009: 2561):

1. Reducing uncertainty through new information;
2. Progressing towards a dominant design;
3. Developing the socio-technical system.

These three elements are here supplemented with special features concerning construction demonstration projects.

Reducing uncertainty by increasing information

Brown and Hendry (2009) and Geels and Schott (2008) describes how product development and introducing innovative elements involves uncertainty and risk. Early design is less proven and experimentation and further learning on the robustness of the design is needed. Schott and Geels (2008) outline a set of areas where learning is needed. More specifically Brown and Hendry (2009:2561) notes that ‘A particularly critical issue is how the end customer might use the product’. The demonstration project, argues Brown and Hendry, would make the product available to operators and users under controlled (and therefore less risky) conditions. And the demonstration project would thus provide new information on technological, economic and commercial aspects (Brown and Hendry, 2009). It is often noted that demonstration projects tends to be overly focused on showing that the technological aspect ‘works’, where customer needs tends to be abbreviated (Schoot and Geels, 2008:541).

Progressing towards a dominant design

The second dimension Brown and Hendry (2009) mentions is the move towards a dominant design. The dominant design is a prerequisite for creating a market for standard products they argue. Importantly Brown and Hendry understands a dominant design as encompassing a particular synthesis of technical aspects with costs and market potential. The establishment of a new dominant design would often occur in a niche environment (Schot and Geels, 2008), “protecting” the new design from the competition from other products established by incumbent actors. Often “new” products would interact and have interface with other technologies and systems and the present, industrialized sustainable building, is not an exception. This systemic
aspect involves that the news can be isolated to a few core elements, whereas many other elements might be considered more of a standard type (Brown and Hendry, 2009: 2562).

Here, in a construction context, we argue that dominant design is not only product design, but also the accompanying design of processes. In construction it is a condition of possibility for a demonstration projects that it involves a usually dominant process of designing and erecting a building with many recurrent element in combination with the innovative non normal processes (Clausen, 2002). Clausen (2002) thus notes that experiences from Danish demonstration projects shows that the innovative element has to compete for resources and often loose terrain as the 'routine' core elements of the building attracts attention. Project management models and incorporation of innovative elements are needed in demonstration projects, to enable establishment of standards for incorporating for example energy producing technologies in housing technologies.

Developing the socio-technical system

The demonstration project does not occur in a vacuum, on the contrary it also represent the aspiration that they might serve as initiating broader supporting institutional change. A new product and design could be accompanied by dissemination of design knowledge, of regulatory change of establishment of new enterprises etc. (Foxon et al., 2009). A process which could also be understood in political terms as developing an advocacy coalitions (Foxon et al., 2009). Schot and Geels (2008) conceptualises demonstration projects as part of a niche development underlining the importance of more players and projects interacting and commencing changing the institutional framework, apart from technical, economic, commercial and social aspects. Brown and Hendry (2009) is underlining that the process towards commercialisation of projects are not linear. Brown and Hendry sees a more feasible understanding as involving R&D experimentations along with demonstration projects. These two learning processes-learning by searching (R&D) and learning by doing(DT)-need to be interlinked in the process towards commercialization. In a construction context however the R&D element is usually directly interwoven with the design processes if at all present. Learning by doing dominates and R&D is viewed as being close enough to any production oriented project (Clausen, 2002).

Summarizing, demonstration projects serves at least three roles, learning (reducing uncertainty through new information) advancing design methods both in process and product (progressing towards a dominant design) and commencing a broader embedding of the new product in its sociotechnical context (developing the socio-technical system).

CASE: A DORMITORY WITH NEW ENERGY SOLUTIONS

To appreciate the innovative element of the present demonstration project, the societal and global context of, 2006 should be remembered (Bertelsen, 2010). The Danish economy and the building sector were booming based on traditional economy with a relative peripheral role of climate mitigation and price development constrained social housing. Only a small handful of players would promote sustainable building or even passive houses. One of the early movers, trail blazers, was the non-profit housing association Fruehøjgaard. The Danish non-profit social housing sector comprises 540,000 dwellings or nearly 21 pct. of the total housing stock. A little less than 1 million out of a population in Denmark at 5,5 million live in non-profit housing. This
society has participated in innovative projects numerous times over the years and wanted to in, 2066 contribute to the development of sustainable build in general and passive houses, and hydrogen technology in particular still maintaining cost efficiency.

The visions and development themes of the demonstration project

The housing association had in the beginning a number of ideas and wishes for the project aiming to support the vision of association (Bertelsen, 2011:6):

1. Very low energy consumption following a passive house standard
2. Value based and lean design and planning in partnering
3. Pre fabrication of the body of the building with high energy standard
4. Costs below the maximum amount given with high value
5. Application of the newest hydrogen technology for heating - and electricity - supply
6. Buildings with focus on architecture fitting to the local environment
7. Buildings with a 'good' indoor climate, which the tenants can feel and sense
8. Lean construction. Learning, efficiency and material control on site

These themes and vision communicated both process and product innovative elements including process elements such as value based lean design and construction. As well as product elements such as low costs, passive house standard, hydrogen technology, prefabrication, good indoor climate. Aim four refers the framing and financing system of the social housing sector, aiming at keeping the costs below the maximum given by the governing ministry. Dwellings are subsidized through tax exemption and a financial acquisition combination of state subsidized loans (84 pct.), interest free loans from local governments (14 pct.) and a tenant contribution (2 pct.). The rent is fixed according to the costs. This means that the rent is kept affordable by balancing it with the costs of the housing estates’ ordinary activities.

The high energy standard aimed at, was made explicit by using the Darmstadt passive house criteria, where the four more important are that specific space heating demand should be lower or equal to 15 kWh per m² per year, the heating load ≤ 10 W/m², the building envelope should be tight tested with pressure test and showing air changes ≤ 0.6/h. The specific cooling demand ≤ 15 kWh per m² per year and total specific primary energy demand ≤ 120 kWh per m² per year (Darmstadt, http://www.passiv.de).

The main players were the client, the architect, the consulting engineer, the manufacturer of prefab element, the contractors and three suppliers of the Micro Combined Heat and Power unit, the unit for electrolysis and the hydrogen installation. A contractor participated from, 2006 in a collaboration constellation with consultants, but withdrew, and one manufacturer participated until October, 2008 preparing a prefab delivery, and was substituted with another.

The process

The initial architect's competition in September, 2006 led to a choice of an architect and consulting engineer. Subsequently a search for ideas and solution within a passive house concept was initiated. The main phases of the project are shown in Figure 1.
Table 1. Plan and Realised phases of the building

<table>
<thead>
<tr>
<th>Main Phases</th>
<th>Plan (beginning, 2007)</th>
<th>Realised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of Consultants</td>
<td>2006, September</td>
<td>2006 September</td>
</tr>
<tr>
<td>Conceptual phase</td>
<td>2006, November-, 2007 April</td>
<td>2007 February</td>
</tr>
<tr>
<td>Development phase</td>
<td>2007 March- November</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td>2007, May-September</td>
<td>2007 May-, 2008 May</td>
</tr>
<tr>
<td>Erection Phase</td>
<td>2007, September-, 2008 June</td>
<td>2009 January</td>
</tr>
<tr>
<td>Occupancy</td>
<td>2008, July</td>
<td>2009, January</td>
</tr>
<tr>
<td>Outdoor areas finished</td>
<td>2009, July</td>
<td></td>
</tr>
</tbody>
</table>

The conceptual design was design commenced in, 2006 as part of the development. In the following the focus is on three innovative element; the passive house design, the prefabrication and the hydrogen technology.

Making a passive house design means an emphasis on energy calculation (Bertelsen, 2010:47). The early process of meeting the Darmstadt standard and the high energy standard in the Danish Building Regulation involved calculations by the engineering consultant using the Be06 software. Be06 is a Danish calculation program required by the Danish Building Regulation. In the spring of, 2007 there was still issues meeting the fist demand of specific space heating demand being lower or equal to 15 kWh per m² per year. The calculations showed a net heating demand of 21 kWh. By July, 2007 the design work were able to meet the certification demands. By December, 2007, unclarity prevailed and it was in February, 2008 decided to ask for consultancy from the Darmstadt experts. This third round of major calculations showed that the third demand of total specific primary energy ≤ 120 kWh per m² per year could not be meet primarily due to definitory issues related to the use of hydrogen. The certification was obtained in late, 2009, almost a year subsequent to occupation.

The prefabrication element was seen as part of the aim for an attractive cost/value balance. A Danish prefab manufacturer participated in the early phase from January to October, 2007, created a prototype of a room module, but had to be dismissed as costs demands could not be met (Bertelsen, 2010:21). A shift was made into using façade elements for a passive house building envelope using a German prefab player, a collaboration that commenced in November, 2007. This can also be seen on the background on the contemporary status on the Danish market for building components. In, 2007-2008 no Danish component manufacturer could live up to the project requirements. Another more standard delivery was that of room modules for the bathroom (Bath cabins).

The aim of using hydrogen technology led to involvement of three specialist suppliers. Their supplies were the three units of a Micro Combined Heat and Power unit, a unit for electrolysis and a hydrogen installation, where hydrogen could be stored. Even if this part was onboard from early on it became delayed and it was only March and April, 2007 the design process commenced. A search for supplementary financing is initiated. By august, 2007 the hydrogen element is taken out of the project with reference to lack of funding and technical problems. However in November the hydrogen element is again onboard in the project. The installation became ready immediately before along with the first occupancy in late, 2008 and January, 2009.

The hydrogen element of the design was not independent of the rest of the design and it led to extra man hours to redesign. Units of the hydrogen system and the other heating systems had to share a technical room, which was too small to give space to both of them, an issue solved by using the room in two floors instead of one.
Results

In the final balance for the project the total cost of erection for the 66 dormitory rooms and the common facility house arrived at 7.35 million Euros (54.8 million DKK) inclusive VAT. As the gross built square meters are at 3.300 square meters, the costs per square meter is at 2.300 euro, which is at 92.4 % of the maximum amount at 2.485 euro/m² set by ministry of social affairs. This means that the cost part of the goal has been met. It should be noted however that this was made possible by a budget reduction exercise carried out in may, 2007 and that many of the participating companies saw the project as innovative and were willing to put aside part of costs as and investment in future knowledge and products. The prefabricated building envelopes cost was at 52 % of the crafts contractors cost, and the bathrooms was 7 % of the costs. This leaves the prefabricated share at 59 % of the craft contractor costs.

As a comparison foundations and outdoor areas occupy 13 %, indoor surfaces and indoor furniture and fittings are 16 % and installations, 19 %. The prefabricated elements has thus been a major element.

The occupants evaluation carried out in, 2010 showed that the respondents value a number of aspects of the rooms and facilities highly (Bertelsen, 2010:60). This includes the valuation of the kitchen and bathroom, the floors, the general comfort and daylight. The lowest score and the most comments however is the response on the question on the heating systems and the thermal comfort of the room. The average score on this question was 2.4. The commentaries received allude to heating problems in the winter, the interdependency of the room heating (one tenant absent links to heating problems in another room). There were also cooling problems in the summer.

The occupants evaluation is in contrast to the evaluation of other stakeholders, even if outright documentation for the indoor and energy properties was not provided, the apology being time and resource pressure in the later stage of the project. Actually indoor climate design played a rather peripheral role in the design process.

DISCUSSION

The following discussion uses Brown and Hendry’s three dimensions of the aims of demonstration project and looks at the projects innovative elements: the process and the product parts. The three dimensions are learning (reducing uncertainty through new information), advancing design methods both in process and product (progressing towards a dominant design) and commencing a broader embedding of the new product in its socio technical context (developing the socio-technical system).

Reducing Uncertainty through Learning

The project provides a host of process experiences, technical, economical and commercially. They encompass the use of a multidisciplinary competence group (value based design), partnering and performance measurement. After a creative beginning the process was forced however into a more traditional controlling, driven by challenges such as the necessity of a German pre fab supplier, the local craft contractors and the economic goals. Energy calculations, indoor climate and issues around demands of square meters became problematic. The quality goal, to obtain a passive house certification reigned over realizing a good indoor climate including sufficient heating. The competency group proved instrumental especially in the beginning of the project when setting up the project (Bertelsen, 2010:64). The subsequent process revealed however that is was a major challenge for the participating players to tackle three main innovative elements, the prefab building.
envelope, the passive house design and the hydrogen heating system at a time (Bertelsen, 2010:65-66). The learning for the product elements relate to low costs, passive house standard, hydrogen technology, prefabrication and good indoor climate. As noted the costs were maintained with the maximum amount given, which is a major achievement. The house also obtained the passive house standard from Darmstadt, probably amongst the ten first in Denmark, as well as the high energy standard in Danish Building Regulation. The post occupancy energy consumption has not been measured however. The learnings related to the obtaining of the certification should provide a competitive platform for the participating companies at least in the social housing sector. Brown and Hendry (2009) underlines the important possible learning when involving the end customers. The occupant's evaluation shows a strong general satisfaction with the rooms on a number of dimensions. However when it comes to experiences with the heating systems and temperature adjustment, this score the lowest in the investigation reflecting yet again that the inhabitants behaviour should not be underestimated in climate mitigation buildings (see also Larsen and Brunsgaard, 2010). It is yet another example of the importance of “details”.

**Advancing and stabilizing design methods**

The project encompassed several elements that could be viewed as progressing towards a dominant process and product design; the energy calculations, the prefab elements, passive house certification, and process elements mentioned above. Whereas the hydrogen technology element was in a much earlier phase of development and was not possible to evaluate. As the subsequent development in construction emerged, the German passive house certification used, have got a role of merely one design approach among several on the Danish market. Several more passive houses emerged from, 2006-2008 (Isover, 2010, Larsen and Brunsgaard, 2010). A competing concept of “active house” was launched in, 2009 and LEED, BREEAM, cradle to cradle and more also emerged. By, 2011 The DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) certification in, 2010-2011 is gaining terrain (Birgisdottir et al., 2010, Sevel, 2011). In relation to apply the German passive house standard in Denmark it must be stressed, that the energy requirements in the Danish Building Regulation must be full filled, and that the German passive house standard can't do that alone.Nevertheless several players have profiled themselves as competent passive house designers and producers, which is still more of a competition of designs. Similarly the prefab element of the building envelope complying with passive house standard, but it has received relatively little attention, as the producer only have been able to sell his concept in two more cases (see below). In parallel to this new industrialization efforts are equally reluctantly adopted in Danish Construction (Thuesen and Koch, 2011)

**Changing and stabilizing the sociotechnical system**

The socio technical systems needed for realizing sustainable prefabricated low cost buildings encompass a set of players such as architects, engineering consultancies, contractors and clients in collaboration with educational and research institutions. A stronger grouping of actors could provide and exchange experiences on emerging design and commercialization. Low cost buildings for social housing and dormitories are a sub group of this. The project itself did involve a study trip to Germany, a website communicating the advance of the project, and an evaluation meant to stimulate learning (Bertelsen, 2010). Even if several players were advocating passive houses from, 2006-2009, the advocacy coalition was not strongly established. Two
other Danish building projects (in Lystrup and Ebeltoft) have used the same supplier of prefabricated building envelope elements, also in the region of central Denmark. Here the supplier collaborated with other players and the project was carried out in parallel. Apart from these two projects there have not been any followers to the strategy of using a German prefab player, nor to the adoption of German building components. Instead the subsequent years showed an introduction of building components and housing in Denmark compliant to German norms (Isover, 2010).

Brown and Hendry (2009) follows demonstration project with large number of installations involved with a longitudinal perspective. They are able to trace some of the elements emerging into a dominant design and even shift in generation of technology. Our research layout asks for a more modest set of conclusions. We cannot claim a change of the sociotechnical system in the direction of low cost prefabricated passive houses, even if the project has contributed to a broader learning on affordable sustainable housing.

CONCLUSIONS

The reported demonstration project of sustainable housing is supposed to prepare the way for future improved and commercially viable solutions. The project demonstrated that it is possible to build four new two storeys buildings with 66 student apartments at passive house standard while not exceeding the normalised costs for social housing. But this is conditioned by how the involved parties in the design- and construction process tackle the details and 'banalities' and still maintain an innovative process.

One 'banality' is the lack of qualified suppliers of prefabricated building envelope elements, which could fuel the competition on energy certified elements at a high standard and low price. A second 'banality' is how quantity and cost are continually controlled risking destroying the innovative and learning in a front running development project. Our recommendation is that the innovation culture in, and between, architects, engineers, constructers and suppliers in the individual building projects must be improved in speed and cost-effectiveness. It includes the calculation of energy through the design process, which must be quicker and adjusted to the needs of the architect and client, and at the same time be related to different standards e.g. the German passive house standard and the different energy consumption standards in the Danish Building Regulation. The third banality is to appreciate the quantitative complexity, as the project manager noted: “Because it is damn important to remember the banalities, when we built”.

The fourth 'banality' relates to whether we improved learning in and between innovation and demonstration projects when in the same period the market dynamics tended to move away from techniques on passive house elements to full filling the tenants basic need on indoor climate. Demonstration project cannot stand alone and must be followed by others, a systematic dissemination process in the sector, which was not the case here. But the project was still a success in despite of the different 'banalities'.

REFERENCES


