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*Published in:*  
Passivhus Norden 2009

*Publication date:*  
2009

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Brunsgaard, C., Knudstrup, M-A., & Heiselberg, P. (2009). Experiences from the Design Processes of the First "Comfort Houses" in Denmark. In *Passivhus Norden 2009* Passivhus Norden.

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Passivhus Norden 2009

27-29 April 2009

Göteborg Sweden

## Experiences from the design processes of the first “Comfort Houses” in Denmark

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**KEYWORDS:** *passive house, energy, comfort, integrated design process, praxis, housing.*

**ABSTRACT:**

*The “Comfort Houses” is the most ambitious building project in passive houses in Denmark until today. Eight single family houses are built and designed by seven different consortiums. Besides fulfilling the German passive house standard the goal was to build the houses according to Danish tradition of architecture and construction. The objective of this research was to clarify the different design processes according to method, tool and teamwork. The processes are evaluated according to the “Integrated Design Process” and the “Traditional Design Process” and show very different take-offs. Analysing the data we can see that: All consortiums agree that it is necessary to work as a team from the early stages of the design process. There is a tendency in all processes that they are not using the tool that are available to document some of the parameters of indoor environment. According to the architectural qualities some of them are often cut back in the process primarily because of cost savings.*

### 1. INTRODUCTION

The most ambitious building project in passive houses in Denmark until today is the “Comfort Houses” [www.komforthusene.dk]. It is a 1:1 scale experiment to see if it is possible to build passive houses in a Danish context according to Danish regulations and tradition of architecture and construction. But also to see if a Danish family likes to live in these houses and to see which problems and barriers this approach gives in Denmark and on the Danish market. The project was initiated by Saint-Gobain Isover Scandinavia and involved building ten passive houses, single-family houses, in the same neighbourhood constructed by nine different consortiums. The consortiums consist both of architects, engineers, contractors and in some cases also manufactures. The houses are finished and available for sale in autumn 2008.

The passive house standard from the Passive House Institute in Darmstadt in Germany is the most well known passive house standard internationally [www.passive.de]. Thousands of houses have been built in Germany, Austria and Switzerland according to this standard. In Denmark passive houses have only been built in the last 1-2 years, therefore we still need to find our own approach. Besides fulfilling the German passive house standard the “Comfort Houses” should also have a high level of comfort – a parameter that the initiators think appeal more to the Danish population than saving energy. The passive house solutions can not be copied directly from Germany or Austria to Denmark because the requirements from the Danish resident’s lifestyle, the traditions in the building industry and the architectural traditions are different. Therefore it is important to find a Danish approach, to get passive houses into the Danish market and thereby minimize the energy consumption in housing.



Figure 1: Overview of the Comfort Houses that fulfils the German passive house standard [1].

It was expressed from the initiators that the consortiums should work integrated with both technical and architectural aspects and work as a team, because many design decisions both affect the energy performance, the indoor environment and the architectural quality of the building. But the initiators did not dictate a methodical approach. In the beginning of the detailing part all consortiums got a fixed budget, which was determined on the basis of the expected market value of the house, and including a small sum to cover the extra cost of constructing a passive house.

The objectives of this research was therefore to clarify the different design processes according to method, tools, teamwork and their approach to achieve architectural quality to be able to use this knowledge in future projects with passive houses or “Comfort Houses” in Denmark. The results will be based on seven of the finished houses.

## 2. METHOD & THEORY

The empirical research of the design processes are analysed through qualitative focus group interviews of each consortium [Kvale 2009, Bryman 2004]. The interviews are carried out after the semi structured interview method. Each interview is analysed individually and afterwards analysed in a comparative study.

In a design process, especially of low energy buildings, it can be difficult to overview the consequences of a certain design decision; therefore theoretically the method of the “Integrated Design Process” (IDP) is recommended and there are different approaches available here. The knowledge from the interviews about the practical experience is compared with different approaches of IDP and the “Traditional Design Process” (TDP) to illustrate which kind of processes the consortiums has had. In the following the TDP and the different approaches of IDP are shortly explained.

### 2.1 The traditional design process (TDP)

The description of the TDP is of course a generalisation but it often proceeds like this: The architect and the client agree on the design concept consisting of the form concept, orientation, fenestration and the exterior appearance like characteristics and materials. Then the engineers and consultants are asked to implement or design systems for the building. This procedure is quite simple mainly because the actors in the process are limited and they are implemented linearly, see figure 2. The linear process results in difficulties in optimizing or even impossible to optimize the design according to e.g. energy and indoor environment, because the expertise comes in late in the process. This is a problem especially when designing passive houses where even more parameters are in action than in standard buildings fulfilling the conventional level of performance.

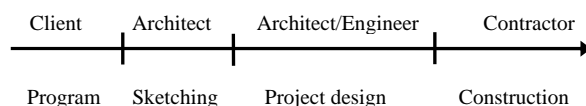


Figure 2: The Traditional Design Process – a linear approach.

### 2.2 The integrated design process (IDP)

In the last several years we have seen a lot of different approaches to IDP being developed. Generally they wish to fulfil the same goal but have different visions of aiming. They all focus on the importance

of integration of aspects of both engineering and architecture in a holistic synthesis in order to solve the often very complicated problems connected to the design of a building. Although they have the same goal they still vary in some areas: Main parameters in focus in the method, steps and milestones, implementation of actors and their position etc. It often depends on who has developed the method and the developer's main professional interest. Most approaches to IDP have an iterative process as illustrated in figure 3.

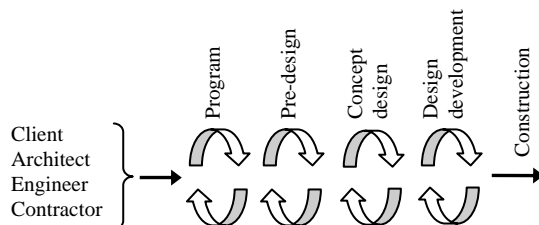


Figure 3: The Integrated Design Process – an iterative linear approach.

Examples of IDP could be:

- International Energy Agency (IEA) Task 23: Optimization of Solar Energy Use in Large Buildings, subtask B (Task 23 IDP) [Löhnert 2003]. In this approach the client takes a more active role than usual, the architect is a team leader instead of a sole form-giver and the different engineers, including an energy specialist, takes an active part in the early stages of the process. The process is based on specialist knowledge of each actor. The design develops through iterative operations.
- The Integrated Design Process, Architecture & Design, Aalborg University (AOD IDP) [Knudstrup 2004, Knudstrup 2006]. This approach is developed as a method for architecture students at Aalborg University, Civil Engineering in Architecture & Design. It means it is developed from an architectural point of view. The work is based on the architects design process applying some technical engineering parameters and tools in the programme. All persons carry a new professional interdisciplinary profile that aims at integrating architectural skills and the necessary engineering skills and tools to fulfil the goals.
- Integrated Design of Low- Energy Buildings, Technical University of Denmark (DTU “IDP”) [Petersen 2008]. This approach is one of the newest methods in field and developed from the engineer's point of view. The procedure in this method is to find the optimal technical solutions in an iterative process between the technical aspects using a tool developed for the purpose. In the end the architectural aspect is incorporated. The question is if the process can be called integrated because the iterative process does not involve the architectural parameters.

### 3. THE TEAMWORK

In the interviews the consortiums agreed that the teamwork in this project was different than they were used to, as it in most cases was based on the TDP. All consortiums talked about the importance of a closer teamwork earlier in the design process and that it is the way forward to be able to make good passive house and low energy building designs in the future. But how they see the teamwork and to what degree the teamwork has been closer, vary from consortium to consortium. The different kinds of teamwork can be classified in three types based on the actors in the TDP.

- Type 1. Incorporated one more actor in the early stages than usual e.g. architect + engineer, but the main influence on the design solution is still from one profession. Later other actors are involved.
- Type 2. Take-off with an interdisciplinary teamwork, but still the design solution is mainly influenced by one or two professions or are based on their premises.
- Type 3. Work as a team together on all aspects of the design e.g. both architect, engineer(s) and contractor from the early stages of the design process.

The different types of teamwork are closely connected to the methodological approach of the design processes described in the previous paragraph. It will be further outlined in the next section.

Besides experiencing the need of teamwork between architects, engineers and contractors, the consortiums within type 3 also wanted to bring in the subcontractors earlier in the process because they are specialist of their own products and their knowledge is also important to integrate to be able to design better solutions both aesthetically, functional, technical and economic.

## 4. THE APPROACHES TO THE TASK

As mentioned earlier the consortiums were not told to use a certain method in the design process of the houses. The interviews showed that all consortiums have worked without a method. Instead they have worked with different strategies. E.g.:

- “Make it simple” as a main guideline
- Outlining a number of focus parameters – some both covering technical and architectural aspects
- ”Trias Energetica” principle [[www.triasenergetica.com](http://www.triasenergetica.com)]
- Performing analysis of consequences of different design solutions
- Or simply designed solutions on the safe side.

These strategies are more and less integrated according to the different definitions of IDP. To illustrate the different consortiums approaches to the process individually and compared to each other, their approach are placed on an IDP indicator in figure 4. The location is chosen from a) the main actor or cooperation of different actors b) when and how the actors are positioned in the process and c) the type of focus parameters in each case. It says something about the starting point for the project and when the architectural and technical aspects are combined – from the beginning or later in the process, if they are combined at all.

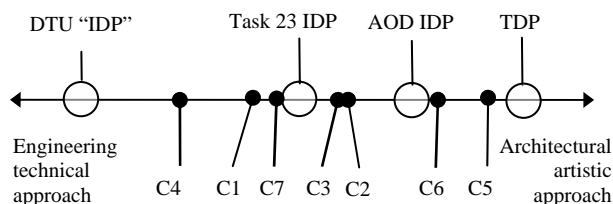


Figure 4: All the consortiums approaches' (Cn) are placed at the IDP indicator. The scale has in one end the engineering technical approach and in the opposite end the architectural artistic approach. They represent the most extreme ends of how to approach a building design. In between them different approaches to building design is placed - the TDP and different approach to IDP. The placement is based on literature study of the different methodological approaches.

The figure shows that the cases are widely spread on the indicator and that the majority of the consortiums have worked very different from the TDP even though they were not introduced to any IDP method. The reason for that might be that the initiators of the project asked the participants to create a consortium and work in teams and share knowledge, even across consortiums. This teamwork must have made some consortiums approach the process more integrated than usual. Maybe they also felt the need to discuss the different aspects to be able to make the right solutions because the concept is new.

The processes have of course not been without problems including the most integrated processes. Consortium 2 has experienced that the boundaries between the professions is more unclear than in a TDP. Even if all actors are present in the discussion and all agree on a decision, it might not be clear who is doing what and when. In consortium 3 they have experienced that even if they have agreed on a certain design aspect, it later turns out that they had different understanding of the decision based on their different professional traditions. In consortium 1 the team is so focused on the “new” technical

engineering aspects that the architect nearly forgets to focus on the architectural qualities of the house. When the architect was asked about which architectural qualities have been important in the design, the answer was that they were closely connected to the energy goals and in answering the architect became aware that they had nothing to do with architectural qualities and says: *“I do not know what architectural qualities there are in that (the answer). I guess it is more some kind of program parameters.”* (The architect, consortium 1). The architect was hypnotized by the quantitative goals and the architectural qualities came in as a second priority.

In consortium 4 the project had so binding constrains that the architect was not able to design good architecture within these. It resulted in architecture, but not as good as it could be. *“Of course you would wish that there had been constructed something ... a piece of architecture, right? But because it should express something that both is typical to a Danish standard house, at the same time something that the contractor could bring out to the market and at the same time be the cheapest, then it had a lot of constrains in relation to the architecture ... The technical part is the most important heaviest in a single-family house in one storey. I think so as an architect. It means that you do not sit down and sketch by a loose hand. You draw a rectangle and send it to the engineer and ask: ‘Is it better now?’ There is no architecture in that, in principal. ‘Should it be a little lower? Arh 20 cm lower ceiling inside’ ... It has been a challenge according to think architecture and at the same time think of a passive house in one storey ... ”* (The architect, consortium 4).

Opposite, in consortium 5, the engineer felt too constrained because the architectural aspects were too fixed. *“I think is was a bit annoying that you in principal sketch a house, and there was not a long time available to do that, and win the competition, wupti! Then you have promised how it should look like, what building services it has and ... the cost. Then you are extremely constrained, right? And that is before you have had the time to consider the design, because you have not had the time to calculate and you actually do not know very much (about passive houses). ... What was it that we were about to do? We had to learn, but we could not use that for anything because we had promised (how it should look like) ... we could have changed a little on the windows ... But we had promised how the house should look like and it is really the architectural idea how the window is placed and turns that direction. Then you cannot change that.”* (The engineer, consortium 5)

When the consortiums were asked to mention some recommendations to others in the building industry they pointed out:

- It is important to have a good teamwork early in the design process and work interdisciplinary.
- The teams have to see the design task as a joint mission and that all aspects concern everybody and all have to be enthusiastic about the project.
- The energy aspects have to be integrated into the architectural expression from the beginning of the design process to achieve good solutions. It means we have to work integrated.
- Draw up some guidelines that should be followed in the design process e.g. define main focus parameters both covering architectural and technical parameters.

## 5. THE TOOLS

In an IDP it is essential to use some kind of tools to demonstrate that the requirements are fulfilled but also to ensure that the design is moving in the right direction during the process. The tools can be divided into three categories: Architectural, energy use and indoor environment. There is a tendency in which tools the consortiums have used, see table 1.

Table 1: The tendency in which tool the consortiums use during the design process.

<b>Architectural</b> <ul style="list-style-type: none"> <li>- AutoCAD</li> <li>- Hand sketches</li> <li>- Some 3D modelling in the sketching phase</li> </ul>
<b>Energy consumption</b> <ul style="list-style-type: none"> <li>- Be06 in the early stages of the sketching phase (Danish software for calculating energy consumption)</li> <li>- PHPP in the detailing part or in the whole process (Passive House Planning Package [www.passive.de])</li> </ul>
<b>Indoor environment</b> <ul style="list-style-type: none"> <li>- Static calculations of the risk of overheating in PHPP.</li> <li>- Other indoor parameters as light and noise are not documented by calculations. The solutions are instead chosen according to the experiences from other building.</li> </ul>



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In other projects they also use the same architectural tools and Be06. But the main difference in this project was that the houses had to be certified as passive houses and therefore the energy consumption had to be documented by PHPP, which was a new tool for most consortiums. The opinion about the PHPP tool varies, but it has been a challenge for most consortiums to get the needed input data, because the detailing of the design has to be higher than usual e.g. detailed calculation of the specific cold bridges and more detailed data of products. The PHPP tool has been used continuously through the detailing process to make sure that the project is moving in the right direction and fulfils the demands. What is interesting is the way PHPP has been used? One way of using the programme is to:

- make a design decision and afterwards check if it is alright with the requirements, if not, redo the design and calculate – “Trial and error”

or

- calculate a reference building and try different changes to that, list the changes and the consequences on the energy use and then discuss what direction to go with the design – “Analysis of consequences”

The latter has been a success for the consortium using this approach and especially a success for the architect, because he gets a common understanding of which design decisions have influence on the energy and how much. They also tried to extend the analysis with an economical parameter. Then the contractor also became active. The first approach is instead split up in specialities, one designs and one calculates. Not saying that it can not be successful to use this approach, but the communication becomes an even more important factor in the teamwork.

According to documentation and analysis of the indoor environment, it has been very limited which tools they have used. In almost all cases the thermal environment according to overheating was calculated in PHPP, but the indoor environmental aspects like light and noise have in the majority of the cases only been discussed. The design solutions were then based on well known good solutions or based on solutions that might accommodate a common well known problem. The consortiums know the tools, but they are not used to work with them especially not on single family houses. The problem in not using the tools is that the solutions they pick are based on existing building cases. The existing building stock are constructed totally different than the “Comfort House” and therefore they can not be sure it will react the same way e.g. the walls are much thicker than in a standard house and can result in less daylight coming into the rooms and the orientation of the house is much more fixed. Furthermore many of the existing buildings have poor indoor environments and the right solution to the problem could be several. E.g. many complain about acoustics in existing dwellings. If it is not calculated and existing examples are poor, how do we know, when we reach comfort?

## 6. THE ARCHITECTURAL QUALITIES

The architectural concept was in all cases defined when handing in the proposal to the competition. Only one consortium changed the whole concept after they qualified for the project but that was a demand from the competition board. In many cases the architectural concept was developed according to passive aspects like compactness, south orientation, passive solar shading etc. Others also worked with a concept of prefabrication or concept of Danish standard housing. It has been investigated if this initial design concept could last through the design process to the final solution or if the consortiums had to make major changes to it to be able to certify the house, to construct it within the financial boundaries and in the same time secure a comfortable indoor environment. No consortiums had to make major changes to the initial design concept, but some things were changes e.g. the amount or size of windows, their choice of materials, shrinking the size of the house and more. It does not seem to be much but some of the actors think it weakened the architecture. Some changes were made to be able to fulfil the energy requirements and the district plan according to building lines, but most changes were made because of the financial constraints. This illustrates that fulfilling the energy requirements is a smaller challenge than fulfilling the financial requirements. It also shows that the indoor environmental parameters have not been a reason for the architectural changes. The fact that



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the economy plays a big role in the level of architectural qualities is closely connected to the fact that architectural qualities are qualitative parameters which can not be transformed into clear definitions and powerful documentation. Therefore architecture has little power in a discussion with other actors in the project [Jensen 2006, Knudstrup 2007]. It is therefore very important in the beginning of a project to discuss the architectural qualities and maybe use some reference pictures to support a common understanding of this. It is a big job to do that because not even architects necessarily agree on how to understand different qualities. To strengthen the common understanding it is important that all actors care for and are enthusiastic about the project also the contractor. Or else it is hard to open up for new insight which is necessary in order to discuss architectural quality in relation to the other aspects in the project – especially economics. The teamwork between the different professions is also important because it create an ownership to the project and trough that create an interest in finding good architectural solutions as well.

## 7. CONCLUSION

All consortiums state that the future design approach is something different than TDP. The future design approach take-off differently and create a different cooperation between the actors in the design process. The analysis show that it is not enough for the client to say that the actors have to work closely together from an early stage in the design process, as illustrated by the seven cases which have shown very different ways of “close cooperation” compared to the TDP. It is therefore important in a design process to define both the teamwork and the methodological approach, as these are closely connected. Therefore if you define a certain type of teamwork you also indicate a certain methodological approach, and vice versa. The investigation show that even in the consortiums where they have worked closely together in an integrated process, they still had some problems mainly about communication and understandings of each others professions.

Some consortiums thought it was only a period they needed to work in an integrated way - until the architect got a better and general understanding of the “new” aspect of building design. But should we go back to letting the architect be the sole form-giver? And let the engineers be the problem-solvers? Do we think it will result in better buildings? The risk in IDP is that the architectural qualities are overruled by all the engineering aspects which also were seen in some of the solutions in this project. That is the whole issue of the differences between engineers and architects [Knudstrup 2006, Hansen 2007]. Architects are generalists and know something about a lot of things e.g. aesthetic, experiences of room, light, materials, everyday life, sociology, psychology and much more. They are trained in combining all these aspects while engineers are specialist and know something about a specific area of the engineering field. Therefore the architect in developing the design is up against integrating several technical quantitative aspects raised by the engineering specialists with his/hers unclear and less well defined qualitative parameters. I think to be able to integrate all the “new” energy and comfort requirements and still design aesthetic and functional buildings in the future, we need to further develop the integrated design approach with a method or a tool to secure architectural qualities in building, especially in low energy buildings and passive houses, where a lot of other aspects are in play.

According to the tools used in this project it is problematic that hardly any tools are used to study or document the indoor environment. That is, as mentioned earlier, a problem because the consortiums do not have the experiences with this kind of houses and do not know the right solutions for sure. Why not do it correctly the first time and use the tools available? People have to live in the houses for more than 50 years.

The result of the analysis seems to aim for a methodological approach and type of teamwork in the IDP indicator region of Task 23 IDP and AOD IDP, see figure 4. It is concluded because of the agreement from all consortiums about the close teamwork from the beginning of the design process and on the recommendations from the consortiums listed earlier in this paper. There is also a more satisfied spirit behind the consortiums placed in that IDP indicator region, satisfied with their teamwork, process and result. Additionally the method of Task 23 IDP is based on the actors’





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individual professional knowledge, which says something about working in praxis when the actors do not carry an interdisciplinary approach. The problems we face in the IDP and in the teamwork are mainly within the communication and understanding of each others professions. A solution to that could be to include a design facilitator (DF) which has the interdisciplinary competences. A DF should have a broad knowledge, understanding and language of both architecture and engineering. A DF should have the overall view of the project and thereby discover unclear issues. For that to succeed it depends a lot on the DF's qualifications in both architectural and technical aspects. He/she has to have a general understanding of both fields but still sufficiently deep to discover problems or unclear issues for the team members to be able to solve them. An architect trained in using AOD IDP could be a good DF because they know the different approaches and tools and can understand the architectural as well as the engineering language. [Knudstrup 2006]

**ACKNOWLEDGEMENTS.** I would like to thank Saint-Gobain Isover for organising the project and the consortiums for letting me interview them.

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