The process behind the project "houses without heating system" in Göteborg, Sweden

Wiktoria Glad
PhD Student
The Tema Institute
Department of Technology and Social Change
SE-581 83 Linköping, Sweden
wikgl@tema.liu.se

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Abstract
In the outskirts of Göteborg, Sweden, twenty terrace houses were constructed throughout 2001. The spectacular thing about these houses is that no traditional heating systems were installed. The commercial's catch phrase is: "Houses without heating systems". Following this project from the beginning and through the whole process, including the long planning procedure (between 1997-1999), the professional actors (the initiator, the building proprietor, the contractor and the researchers), come into focus. This is a unique project in Sweden and has not yet had any follow-up developments. The evaluation, mainly including measurements, is being conducted by a research institute and will be finalised in 2003.

The theoretical approach is as described in socio-technical system and focuses on social and technical components. The point of departure for the study is the social subsystem and the process behind the project which is important in understanding the final outcome. The study focuses on how and why this project was conducted. Initially, one person's ideas, inspired by building projects abroad were crucial. These ideas were then spread to a network constituting of researchers, the building proprietor, the contractor and the builders, and other consultants. The process can be described as a social innovation since a new concept for heating in buildings is introduced by focusing on the planning process and new participating actors.

In the analysis social-technical systems approach is used. It is possible to trace an actor who has been present in every phase and who has acted as a driving force in the process.

Introduction: what is "Houses without Heating Systems" and why study the process?

The project "Houses without Heating Systems" was introduced in 1997 when an architect formed a network of scientists and filed an application for financial support for a research project. The plan was to build ten to twenty terraced houses in Hannover (Germany), Malmö (Sweden) and Göteborg (Sweden). This project had a goal: to reduce the loss of energy from buildings before focusing on the issue of supply. This could be obtained by well insulated walls, energy efficient windows and an efficient heat exchanger. These technologies are all accessible on the market but have seldom been combined in this way, especially not in Sweden. Apart from the technology mentioned, passive heating from human beings living in the houses and their use of equipment in the house: lamps, the washing machine, the tumble-drier, the TV, computers etc are important contributors to the indoor climate in these houses. Solar thermal systems, for producing hot water to the individual households, were decided on in an early stage and not discussed in particular during the planning process.

However, the process from having a vision and to realising these ideas is not an easy one. This was noticed by the initiator so a lot of effort was put into the process and the participants. The key idea was that knowledge from different professions could be handed over to others in the project and in this way, mutual understanding of different profes-

sionals' unique problems could be obtained and problems could be solved together. This process will be analysed in this paper.

BACKGROUND: THE SWEDISH ENERGY POLICY AND THE GÖTEBORG SETTING

Dwellings account for one third of all energy use in Sweden and is an important sector to take into consideration since Sweden's energy system is about to change. This change is supposed to lower the impact on the environment, particulary the climate (Regeringens proposition 2001/2002:143).

Sweden is said to be a leading country when it comes to energy regulations in national building policies. However the building sector is undergoing a change towards less consideration into energy-saving. There are other ideals in this sector today. The responsibility for implementing the building policy falls on the building proprietor, the municipality no longer possess that competence. Internationally, Sweden is no longer in the lead when it comes to implementing strict policies (Eek 2002).

In Sweden, electricity is comparatively cheap and there are several alternatives for heating a house: one is district heating which accounts for 40% of the total heating demand in the sector for buildings and dwellings. In the small house sector the share is around 8.5%. One third of all small houses are heated with electricity (The Swedish Energy Agency, 2002).

Göteborg is the second largest city in Sweden with 471 000 citizens. Since 1996 there has been an environmental policy "På väg mot en bättre miljö!" (Towards a better environment) which is supposed to give the city an explicit environmental profile. The environment is said to be a priority and that it should encompass the whole municipality, including the corporations owned by the municipality. (Göteborgs stad, 1996) Every municipality in Sweden is supposed to have an energy plan. The energy plan for Göteborg was revised in 1994, but was never accepted by the decision-making board. Despite that, the plan was put into practice. One goal in the plan is to guarantee energy supply at a low cost. (Stadskansliet i Göteborg, 1994) Both these policies were revised in 2002.

The twenty terrace houses in the project "Houses without Heating System" were built in the district of Askim, a part of Göteborg that is characterised by its attractive location, close to the sea, and defined as a high income area.

PURPOSE

The overriding aim of this study is to analyse the process behind the realisation of this project and the twenty houses. This will be done by using a socio-technical perspective. The main objects of study are the professional actors who were involved in the process. The following issues will be explored with in this paper:

- Why did the project "Houses without Heating System" start? What ideas were found among the professional actors? What were the prerequisites for the project (outside the project group)?
- How was the project accomplished? What were the important parts of the process? In what way did the professional actors influence the final shaping of the houses and the technology used?
- What were the effects of this project? What has the project led to so far and what is the potential for the future?

Excluded in this study are technological details and questions on whether the process has been efficient or not. The empirical work excludes national building regulations and most parts of the documents of requirements for this project.

METHODS

This paper is a case study based on written and oral sources of data. The case was chosen for an in-depth study for several reasons. First, it is a unique project in Sweden and there is no opportunity to compare this with similar projects nationally. Second, the project is also part of the overall goal in the country to reduce energy demand in the housing sector.

The interviews were the most important sources of data. Around forty professionals were involved in the project, but only ten were selected for interviews. The method used in the selection process is called "network selection" and makes use of the respondents own answers to the question: "Who would know something about this?".

This study is part of an interdisciplinary project that took place from October to December in 2002. Several more aspects of the houses were studied and are published in the working paper *Tvärvetenskaplig analys av lågenergihusen i Lindås Park, Göteborg* (Interdisciplinary analysis of the low energy houses in Lindås Park, Göteborg). This project was part of a course in the graduate school called "The Energy Systems Programme".

THEORETICAL APPROACH

This study has an interpretive approach which includes the researcher. Therefore, the point of departure has importance for the conclusions since the researcher chose a perspective, one among many.

In this study, the theoretical point of departure is that the process behind a building project is important to study since the outcome is greatly affected by conflicts and negotiations during the process. It is therefore impossible to foresee the outcome at the beginning of the process. In this case it was also interesting to follow the process because the initiator put so much effort into making this process different from common building procedures.

The concept "process" is used to emphasise on the meandering character of a project; the route can rarely be predestined. It is seldom linear and the final product is a joint venture for all the participants.

Socio-technical system

By exploring houses as a socio-technical system, some theories have been important in defining "socio-technical" and "system". The system approach uses the concept "system" in a way quite similar to the common language: a system consists of *components* and *connections* between the components. The system is separated from the *environment* by a *boundary* (Ingelstam, 2002).

In a socio-technical system, the system consists of social and technical systems and they can never be separated. The

social subsystem includes social components and connections, the technical subsystem includes components and systems and there are connections between social and technical components.

In this study the point of departure is the social subsystem thus the technical subsystem is not prioritised. This does not mean that it is not important. On the contrary social components have several connections to the technical subsystem which will be identified in this paper.

Defining the boundary is crucial in the analysis. In this case the system includes the buildings and the professional actors in the time period 1997-2001. Some aspects in the environment were mentioned in Background but connections between the environment and the system, as defined above, are only present to some extent in the empirical findings. This is presented in Conclusions.

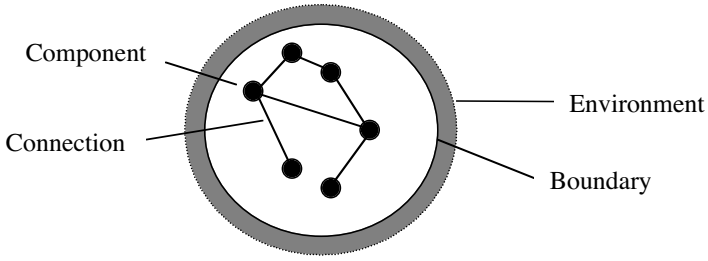

Figure 1. Concepts in system approach. *Components and connections are the most important concept in this approach. Yet, the definition of the boundary is crucial (Ingelstam, 2002).*

Large technical systems, social construction of technology and actor network theory

The economic-historian Thomas P Hughes has done research on large technical systems (LTS) the system of electricity, using a socio-technical approach. In *Networks of Power* Hughes follows actors in their work and identifies different phases in the history of electricity.

The first phase in Hughes investigation consists of invention and development, where the professionals involved are mainly inventor-entrepreneurs, who are part of the process from idea to realisation. Hughes describes how engineers, managers and financiers are also involved and how they take more and more control over the system. The second phase focuses on how the technology is transferred from one region and society to another. Characteristic of this phase is how participants other than the inventor-entrepreneurs act as "agents" in transferring the technology. In the third phase, the system grows and faces *critical problems*[1] and *reverse salients*[2] *which hinder the development and expansion of the system. The fourth phase is reached as the system acquires momentum; the system now has a predestined goal and the direction is difficult to change. Social components surrounding the system are an important part of the momentum. (Hughes, 1983)*

Social construction of technology (SCOT) and actor network theory (ANT) are two perspectives in sociology using a socio-technical approach. In SCOT the sociologists Wiebe Bijker and Trevor Pinch describe three stages in the development of a system or a product. In the first stage there is a great amount of interpretive flexibility of an invention or scientific findings. Different *relevant social groups* have different interpretations of this news. These groups have possibilities to influence the development and in the next stage there is possibly a discussion about the interpretation. The acts of the relevant social groups make them form and exclude some interpretations. By this *stabilisation*, the process is facing *closure*, an agreement on how to define the new technology. The third stage is reached when the technology or system has to be related to *the wider socio-political milieu*. (Bijker et al, 1987) SCOT is part of the system approach despite the fact that the theory emanated from empirical studies of the bicycle. Even simple technology is part of a complex socio-technical system (Ingelstam, 2002).

The use of the concept *network* in ANT might be viewed as synonymous to system, but it has also been criticised for ignoring the boundary between the system and the environment (Ingelstam, 2002). The network is built by the actor or entrepreneurs with the purpose to realise an idea. Conflict and struggle for power are important aspects of this theory (Summerton, 1998).

LTS has been criticised by John Law for stressing the importance of the technology and SCOT focuses too much on the social components. In ANT the social and the technical components are symmetric in the analysis of a technology or system (Ingelstam, 2002; Law, 1987).

Professional actors

In studies using LTS the most common concepts used are the phases described above, reverse salients and *system builders*. System builders are the entrepreneurs of the system. The characteristics of these system builders are their visions of the system and their steady work to realise this vision. The similar concepts *actor*, *entrepreneu*r and *engineer* are used in the actor network theory introduced by Bruno Latour, Michel Callon and John Law. (Summerton, 1998) A *member of a social group* in SCOT is also similar to system builder and actor (Ingelstam, 2002).

The resemblances between the actor network theory and the theory of large technical systems are that they both focus on a single actor as a driving force. Political, technical and social factors are mutually dependent in these theories. These theories have been used to analyse energy systems in several research projects (Summerton 1992; Kaijser, 1994).

In this paper the concept "professional actor", and sometimes just "actor" is used. This concept should be considered a synonym and can be described as a person who has a position in an organisation which legitimises their influence in the process. Certain actors might be of specific importance in a project when acting as the driving force (Wihlborg, 2000). In this study an actor is a person who is part of the process behind the project "Houses without Heating System".

1. *Critical problems* refers to the process of defining problems so that they can be solved, usually by the engineers.
2. *Reverse salients* are a concept from military history referring to areas of imbalance where some section in the front line has fallen behind.

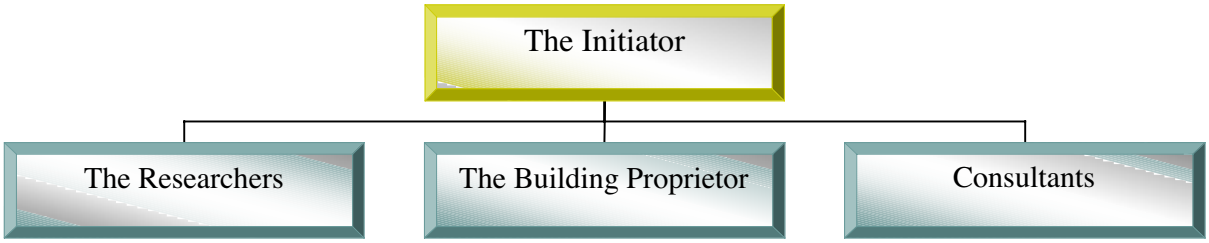

Figure 2. The initial roles of the actors. *During the idea phase the initiator was the most important actor leading the network of researchers, the building proprietor and the consultants.*

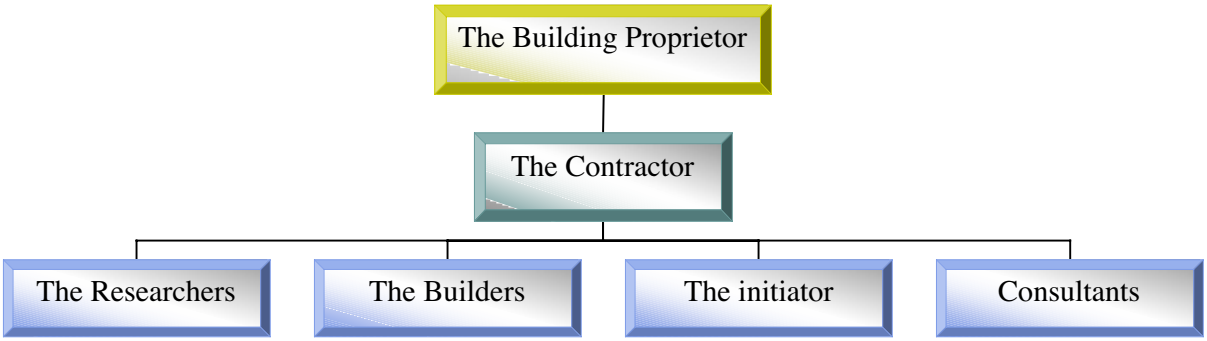

Figure 3. The actors during the building projection phase. *The building proprietor was the leading actor throughout this phase.*

The actors studied had different roles in the process. They are architects, a building proprietor, a contractor, researchers and consultants. Some of these actors have had the same role during the whole process while others have shifted roles at some point. First, the initiator had the role of initiator, architect and co-ordinator. The researchers had a common role as researchers which included applications for financial support. The building proprietor had the same role throughout the process and took over the responsibility for the project when they decided to join. The contractor entered the project as a contractor for the whole building process as a result of a buying procedure. Normally, this implies that the contractor has control over the projection of a building project as well as the actual building.

However, this building project was somewhat unique and differed in the process compared to conventional building projects. As the project entered the building projection some of the actors changed roles to become consultants engaged by the contractor. At the same time, the research part of the project went on. The initiator acted as a co-ordinator and the researchers continued their original role.

The researchers are evaluating their own research project. This might cause a problem since the researchers are evaluating a project which they have been engaged in and they are for that reason not impartial. The initiator and co-ordinator, who also is an architect, is now involved in marketing the project in different ways. The contractor is no longer involved in this or any similar project. The building proprietor is the administrator of the tenant-owned flats and is also involved in providing information about the project when students and the media contact them. People who moved into these houses play an important part in marketing the houses and they are also part of the evaluation of the project as interviewees. Their opinion about the indoor climate might be crucial to the future of this concept in Sweden.

This analysis has not involved the residents as actors, or as they can be called: the users of the houses. This is because they have not been involved in the process behind the realisation of the houses. The flats were sold at a late stage in the whole process and this was the only time the users had any influence on the outcome. The users play an important role in marketing the concept, but that is not analysed in this paper.

Social innovations

The concept *social innovations* is used to identify successful strategies in energy efficient measures by the Swedish research group *The Environmental Strategies Research Group* KTH, Stockholm. In history, the development of technology and systems has been preceded by changes in social components and connections. This has been the case in the development of gas in cities, the rail road and the urban water system. The concept is important to stress on how changes in less sustainable systems is achievable. Social innovations are defined as partly "changes in fulfilling needs and manage different supplies", partly "changes in how to organise production and distribution" (Jonsson et al, 2000).

Social innovations might be new concepts or new fields of activities for the municipality and co-operation between public and private spheres. It is possible that a common in-

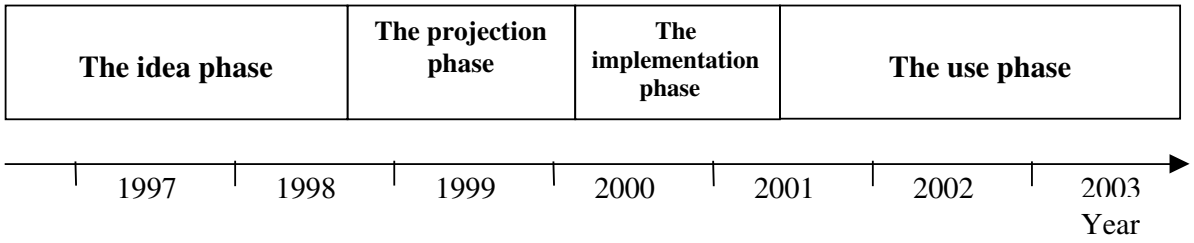

Figure 4. The phases in a time dimension. *The process has been analysed as four different phases.*

terest can be identified between different sectors of the society and both public interests and private demands on profit can be fulfilled. One important aspect is how problems are defined and how actors usually think about problems. Social innovations are also described as new combinations of goods, services and individual work to meet the demands of infrasystems[3]. This may also include innovations or new socio-technical systems (Jonsson et al, 2000).

In this case *social innovations* is used to describe how the process behind the project "Houses without Heating System" is managed in an unconventional way by the initiator and the participating professional actors.

Description of the process

The process behind the project "Heating without heating system" is divided into four different phases. As the phases are not exclusive, different events can belong to two different phases. Different actors had different ideas about these phases and all actors were not involved all the time. The purpose of sorting the events into phases is primarily to facilitate the analysis.

The phases are in brief:

The idea phase: when the initiator went from a vision of energy efficient buildings to introducing the concept to others. To be able to realise these ideas, a network of persons with a variety of competences had to form. In the early stage, informal meeting were held and as the problem with financial support was solved, formal meetings were organised.

The projecting phase: when the contractor became engaged in the project and the process was more market oriented financially. This was also a point when the project shifted leaders. As the project came closer to the actual building procedure, the local manager became more important in the process.

The implementation phase: here the building of the houses started and the process was in the hands of the local manager. Simultaneously, the building proprietor tried to sell the proprietorship of the flats to 19 different private owners (the last house was supposed to be rented by a Swedish research institute for detailed evaluation). As the selling failed, the houses turned into tenant-owned flats.

The use phase: here the actors had different strategies to take care of their obtained knowledge and experiences from the project. Some were still involved with the evaluation and the marketing of the project. During this phase the most important actors of the process were the users; the residents. Their everyday experiences in their homes are the key to whether or not the concept will be accepted as successful.

The phases can be described in a time diagram (see Figure 4).

THE IDEA PHASE

The least common denominator among the participants in the project was the interest in energy efficient technologies in buildings, at least for most of the participants. This interest was especially prominent with the initiator and the researchers. The initiator used this interest as a base for the initial network of actors. In this phase the initiator, who is also an architect, appeared as the driving force behind the project.

Some of the actors in the network had experience from the energy crises in the 1970's which initiated their interest in issues concerning energy in buildings. In 1980, Sweden conducted a national referendum on nuclear power. The debate that preceded this occasion is still a living memory among many Swedish citizens including some of the actors in this project. Some of the actors also expressed their frustration over the slow motion of development in the energy sector. The initiator founded an architect's office in the 1970's based on ecological values. During the following years some building projects with low energy features were developed but comprised of both negative and positive experiences. Some positive results came from projects in Germany and the German Passivhaus Institut has served as a source of inspiration. The project "Houses without Heating System" was first planned to be built at the Hannover Expo 2000, but the initiator also proposed the idea to Swedish building proprietors. None of the bigger firms responded to the ideas but a minor local firm, owned by the Göteborg municipality, showed interest in the project.

Several researchers had a background in participating in projects with the initiator. In some sense, the participating research institutes had already formed a network, but the personnel had changed. This was the first time these individuals worked in a project together. The common interest in energy efficiency in buildings held the group together and one interviewee said "We can talk, communicate and understand each other very well" (Actor G, 2002).

3. Infrasystems are the large technical systems for transportation, energy, water and communication in society (Kaijser, 1994).

The building proprietor should, according to their homepage, "be considered as the leading building company in the small house sector in Göteborg". As part of their obligation is to "engage in the development of the municipality" an interviewee said that in participating in this building project, the company could take a leading position in the development.

Essential to the proceedings was financial support from a research council. At first a fund for planning was granted and later applications from the different research institutes were accepted by the council.

Initially, the basic ideas behind building houses without a heating system were easily accepted by some of the participating actors. Others were more sceptical and described how they were convinced. In this case the initiator played an important part in describing the technical systems making them understandable for many. The fact that similar houses had been built successfully in Germany contributed in convincing the sceptics. In the later phase of the project these actors, when meeting a sceptical person outside the project, became the advocates. One of the interviewees still sounds sceptical due to some economic and technical aspects of the project which will be discussed later.

The seminars were the first formal meetings held within the realm of the project. All of the participating parties were invited but not everybody showed up. Despite that, several categories of professionals were present. The purpose of these seminars was to spread knowledge from the different categories of professions participating. In that way a common platform for collaboration was funded. Every seminar, there were approximately ten, had a theme presented by one of the participants, mainly the researchers. Although the seminars were important the actors found them time-consuming and expensive as the time allocated for this purpose was too little and also travel expenses exceeded budgets.

THE PROJECTION PHASE

Simultaneously with the last seminars in august 1998, the projection of the buildings started. Some of the actors had difficulties separating the projection meetings from the seminars during the interviews. One explanation might be that these different kinds of meetings dealt with the same issues. Despite the confusion, the project had entered a different phase since this was a market-oriented part of the project and the contractor was then in charge of the procedure. The researchers seldom participated in the projection apart from the institute that was responsible for the careful measurements in the final phase of the project. A representative from the architect office was always present in these meetings. New actors in this phase were the consultants.

The difference between this projection and conventional building projection is that it differed in the number of meetings and in the sense that researchers and architects influenced the project, even at this phase. The researchers describe their influences in this project as different from other projects; often the researcher is called in as a consultant at a later stage, when mistakes are more difficult to manage. In this project researchers are part of the whole process which was considered a positive aspect by the researchers. From the constructor's point of view, the influence of new actors in this phase was odd and negative. New ideas and demands arose continuously from different actors and had to be dealt with. Often these demands changed the economics in a less than favourable way. One actor described how "there were severe discussions sometimes" in this phase (Actor G, 2000). Another actor said "It was really important that we achieved consensus on the different solutions that we worked on" (Actor H, 2002). One actor summarised the projection phase as "you had to give and take like in all projects" (Actor A, 2002).

For one year, from the beginning of 1999 to January 2000, the whole project was delayed due to a difficulty in the planning procedure. Through the building site there is a cable for transmitting electricity between Sweden and Denmark. This was thoroughly investigated and it was concluded that the cable was harmless to the residents. This delay influenced the economic conditions for the project.

THE IMPLEMENTATION PHASE

In the implementation phase, the important actors were the local manager and the builders, and as will be shown, the initiator. The local manager only participated in a few meetings during the previous phase. The contractor intended to use another person as the manager, but since the project was delayed this person was exchanged. The initiator met with the new local manager and they were on good terms with each other during the implementation phase. Some of the actors described the local manager as an important actor in this phase since he had a critical eye and did thorough work.

Since the architecture and construction of the buildings required special skills, the local manager hand-picked the builders. Besides the manager, the architect and often the initiator were frequent visitors at the building site. This is a rare situation in Sweden; the architect is seldom part of the whole process: from the idea to implementation. In this case the architect played an important part in teaching the builders about the concepts of this project and what was required in this building phase. One important procedure was building the thick and dense walls, which was an important part of the concept. Since the initiator had this close contact with the workers on the building site, he was still "the spider in the web" for this project.

During this phase visitors were a common feature at the building site since the project evoked the interest of many. The local manager described the visiting groups as an interesting and fun part of this project. The competing contractors on a nearby building did not receive any attention.

The flow of material for the project was a factor that caused delay. The dense walls needed more insulation than regular buildings. The local manager said "the quantity of material matched a building project of 50 houses, not twenty as in this case". The flow of material and the building of the dense walls demanded more time than usual. The building proprietor responded that a significant and special aspect of this phase was "the engagement among the builders".

Parallel to the building procedure, the building proprietor started the marketing of the terrace houses. In this stage the houses were advertised as private proprietorship. Information about this opportunity was sent to people in the company's housing queue. This announcement did not receive much attention from people despite the fact that the demand for small houses in this area was high. Some of the in-

terviewees thought it was the sketch from the architect that caused this reaction. On the sketch the roof looked like reed and not sedum, which the architect had in mind. A roof with reed gave the houses an ecological touch which implied a higher risk when privately owned. After this incident the roofs were covered with tile and sold as tenant-owned flats mainly during October and November 2000. With this type of ownership the building proprietor still had some responsibility for these buildings after the flats were sold. Although the houses were more expensive to build, due to unconventional procedures, and the extra cost for insulation, high efficient heat exchanger, windows with low U-value and solar collectors, the price was similar to prices in the regular housing market in the area. The building proprietor guessed that the tenant-owners bought their flat mainly because this is an attractive site. Afterwards, the tenant-owners expressed interested in the technology used in their houses.

The user phase

In springtime 2001, the residents moved in. This phase will only be described in brief since it mainly includes the residents who have not been studied empirically.

In this phase the actors used different strategies to move on. The initiator was mainly working with showing the buildings to visiting groups and trying to spread the word. The building proprietor was interesting in follow-up developments, but found it difficult to raise funds and find a suitable site. The initiator and the building proprietor were still in contact with each other. The contractor claims they have no prospects for new similar projects since this one was too expensive. The researchers are finishing their final reports during 2003 and one of the research institutes are involved in careful monitoring of the twenty houses. One of the houses has been used as a testing house since 2001.

Different perspectives on the process

The analysis below is based the process as described above. Perspectives of specific importance to the process and the final outcome have been chosen. The goal of this section is to provide a deeper understanding of the events in the project.

THE PROCESS AS A SOCIAL INNOVATION

In this case a social innovation might be the emphasis on the process behind the project "Houses without Heating System". This was an idea that originated from some of the participating actors and the initiator still emphasises the process as an important part of the project. The participation of many actors early in the planning process and the learning processes that everyone experienced most certainly had a positive effect on the final outcome and the quality of the houses. Knowledge and know-how were exchanged between the actors and learning plays an integral role in the process. Lack of mutual understanding between the different categories of actors was something that was identified as an obstacle to overcome. One of the goals with the research project was to achieve mutual understanding among the categories.

The seminars which took place in the early stages of the process were one important part to achieve that goal. The seminars boasted a variety of professions. Some of them took more time than the participants had assigned and including travel expanses this was a factor that affected the project's total budget negatively, putting stress on individual actors. One actor states that 30-40 percent of their budget was used up during this stage.

The actors met several times and there were many opportunities to discuss different technological solutions. Also new ideas were dealt with and explored. One of the actors describes the events during the seminars as "everybody wanted to build a monument, it was like: look how good I am" (Actor I, 2002). For this actor, the seminars were frustrating and "there were unreasonable demands which you didn't need; it is only a dwelling" (Actor I, 2002). As the project continued the actors were given new roles, and former leaders became consultants. This caused confusion concerning where the final decisions were made. One actor states "I remember that we had an agreement on not to have it [a certain technical solution], nobody wanted to proceed, but I don't know whether it was a formal decision or not" (Actor H, 2002).

The emphasis on the process was new to all the participating actors and some friction between different professions was expected. Most of the actors seem satisfied with the outcome and some even have plans for new common projects, although the financial side will be a deciding factor. One important lesson is that a process with many participants is time consuming but today the building sector has a tendency to speed up the implementation stage even more.

AN ACTOR AS A DRIVING FORCE

The phases described above correspond to one of the phases found in Hughes' study on the electrification of the western world in *Networks of Power*. In the first phase of Hughes' description there are some similarities to the process in the project "Houses without Heating System". One important characteristic in Hughes' first phase is the important role of the inventor-entrepreneur. In this study the initiator acted as an inventor-entrepreneur, with an important difference: the initiator did not invent the technology, as Thomas Edison did. However, this new combination of technologies, the energy system of the building, was in some ways unique.

The initiator identified problems in conventional building processes such as: lack of mutual understanding between different professionals, experts were called in as consultants too late in the process, in conventional building project the quality was too low to correspond with the demands in this project etc. By identifying these problems in an early stage, these difficulties did not dominate the project.

Another feature in this process was the ability of the initiator to have some kind of control in every phase of the process, from idea to realisation. Other actors in Hughes' study were also important but they did not preside over the project and the system. In this project, the initiator formed a network of system builders including a variety of professions but never let go of the control, even at the building site.

Networks of Power focused on great men, inventors and engineers and LTS has thus been accused of drawing attention to famous men and successful projects. In the project described in this study, almost all actors were men. In the interviews three out of ten interviewees were women, two of

them an architect and an engineer. When including consultants and builders among the actors the women represented an even smaller part of the participating actors. The initiator was a man. Whether this concept will be successful or not, time will show.

THE ACTORS AND THE TECHNICAL SUBSYSTEM

Even though there were no inventions involved in this project some development of existing technologies did take place. The technologies used in the project were described by the initiator as "simple" because they were known and found on the common market.

The "simple" technologies were supposed to be: super-insulated exterior walls, windows with a U-value of 0.85 W/m²K on every window, solar thermal systems for hot water (covering 50 percent of annual requirement), high-efficiency heat exchanger in the ventilation system (90 percent temperature coefficient of performance). These technologies are not new but are high performance types. The building of the super-insulated walls and the heat exchanger in the ventilation system has in some sense been developed within this project.

The thick walls were proved to be extremely dense, four times more than ever measured in Sweden. The building technique used was described as complicated and time consuming by the local manager and the builders, but also one of the most crucial parts of the building procedure.

The heat exchanger has a story of its own. According to commercial brochures from heat exchange sellers in Germany, there were heat exchangers with 90 percent temperature coefficient of performance on the market. One research institute was sceptical about how the measurements had been performed on these high-efficient heat exchangers. In the Swedish institute's laboratory tests the temperature coefficient of performance was less than the value in the brochures. Parallel to these laboratory tests, a technology contest on heat exchangers was announced by a Swedish national research council. When the heat exchanger companies were faced with demands from the project "Houses without Heating system" and participated in a contest, some achieved a higher performance. One of these heat exchangers was chosen for the low energy buildings in the project.

Within the project group some participants were sceptical about whether the heat exchanger alone could manage a comfortable indoor climate in the buildings. As these actors were unwilling to proceed unless this problem was investigated, the suggestion to add a warming battery to the heat exchanger was discussed thoroughly. The choice to install this battery was a way of reducing the risk in the project , however by adding a battery "just in case" meant that it was now a house with a heating system. Some of the project's critics have focused on this matter. Since the residents moved in, the battery has been used more extensively than expected by some of the professional actors (Boström et al, 2003).

When installed in the houses, none of the technologies mentioned had these high performances for different reasons. In short: The contractor chose another supplier for the windows than the architect had in mind. The windows accomplish the U-value of 0.85 W/m²K as a whole but some windows have a higher value. The solar thermal system only accomplishes coverage of 37 percent of annual requirement. The system is dimensioned for a household of four people and in a household with two people who are seldom home, the losses from the system are greater than the gains (Boström et al, 2003).

ENERGY EFFICIENCY AND THE SYSTEM APPROACH

The least common denominator among the professional actors was an interest in energy efficient technology solutions; this applies to everybody except for the contractor and the builders. The contractor and the local manager were introduced to the overarching ideas of this project: to minimise energy use by building a thick, dense construction stopping heat from leaking out.

The initiator stated that when building a house it is important to manage the leakage of heat before even considering a heating system. The calculations by the researchers and experience from abroad showed that it was possible to build terraced houses in Sweden without a heating system. As the description of the process of choosing between technologies shows, a battery for warming the incoming air in the heat exchanger was added.

The goal of the project was to make an energy efficient house way beyond Swedish regulations. This was accomplished as the flats has a total demand of energy between 58-71 kWh/m² compared to a regular small house (including residential buildings, terraced houses and chain-houses) of 152 kWh/m².

Apart from energy efficiency no other environmental aspect of the buildings or the residents was considered. Compared to two of the largest new dwelling areas in Sweden, Hammarby Sjöstad in Stockholm and Västra Hamnen in Malmö, this was a single task project. In the concepts of Hammarby Sjöstad and Västra Hamnen other aspects of the building of sustainable dwellings have been included e g transportation and waste management (Brogren, 2001; Green, 2002).

Accordingly, the actors have limited the system to only include the buildings and their energy systems. Neither the local environmental plan nor the energy plan were consulted in the project. This was more of a national project since it was financed by a national research council. The building proprietor was however a local company and as an important actor in the implementation phase the local community had some influence on the project.

FINANCIAL ASPECTS

One purpose of this project was to show "how far you can reach with known technology and reasonable costs to achieve a very energy efficient building with good thermal comfort" (Eek, 1998). By not installing a conventional heating system some costs were also saved. This was in part why the project received financial support from the research council. One actor stated that "with common knowledge, for most of the part, with simple technology and simple measures it is possible… to build terraced houses or small houses which use very little energy… and to do that without a lot of extra expenses".

Some actors in the project participated on the common market even in this project. The building proprietor, the contractor, consultants and the buyers all took a risk in in-

vesting in this concept. Some of the professional actors made a tender lower than reasonable, according to some of the actors. The buyers were not eager to take the risk of owning the houses privately. The houses were sold quickly as tenant-owned flats even though the total amount of money spent per month will be the same for the households.

The building proprietor and the contractor stated that this project was expensive and that it would be difficult to manage a new similar project. This concept has not been implemented in other projects yet. Another reason, aside from finance, is that it is hard to find a suitable site. A positive effect is the knowledge that the participating actors have gained. The project has also received much attention from the media, both locally and nationally. Often it is the residents or the initiator who the articles and reports have focused on.

Conclusions

The process behind the project "Houses without a heating system" has been analysed from the position of the participating professional actors. The main task within the project was to build low energy terraced houses with a good indoor climate and manage with available and "simple" technology.

One important element of the realisation was the initiator who was the driving force behind the project. He was in control during the whole process like the inventor-entrepreneur in Hughes' theory on large technical systems, the first phase. This actor managed to transfer knowledge and know-how through an organised learning process in the seminars. Possibly, the informal meetings were also important. As new actors entered the project, the learning process continued, often with the initiator involved. The local manager from the contractor and the builders were last in line. Later the residents also went through a learning process with information, trial-and-error and finally learnt to live in these houses (Boström et al, 2003). The initiator was important partly as a catalyst in the beginning of the project, partly as a problem identifier and "teacher" throughout the process. In this way, the initiator was in control throughout the entire process.

Each continuing phase in the process was dependent on the phase before. All the phases had a different actor as a driving force but the initiator was present and important in every one. During the idea phase, the initiator had the strongest influence since the concept was described and the different technologies included. The identification of problems was crucial as it influenced the selection of participating actors. In the seminars, the researchers had influence as presenters of their scientific results and in discussions of the best technology to use. Practicians also influenced the process by sharing their know-how with the rest of the participants. This know-how was even more important during the projection as the leader of this process came from the contractor. Both the seminars and the meetings during the projection served as building a common base of knowledge.

It is difficult to identify factors outside the project group that has been decisive for the project. Most of the proceedings of the project were due to internal factors: the driving actor and the competent network with a common interest in energy issues. By financing parts of the project, the national government through a research council, participated and supported the project. The local government was represented by the building proprietor who is owned by the city of Göteborg. Competing companies in the building business also supported the project through low bids. Despite an exceeded budget for some of the participants, the houses were built on time, except for the one year of delay due to external factors, and with good quality (the denseness and acoustics were measured). The initiator and the researchers are part of the international scientific community and are familiar with low energy building projects abroad. That context affected their knowledge and interest in this project.

The actors influenced the outcome partly by not choosing the proposed technologies and partly by carrying on research to accomplish these high performance technologies. The technology does not work as assumed but the concept, as a whole, seems to work so far. The important technologies installed in the buildings all have different stories to tell which shows that it is not always the best that wins.

This project has not had any successors yet. Some of the actors claim that it has to do with financial issues; this project was expensive and it is difficult to raise funds for new projects. These houses have, however, attracted attention from the media, locally and nationally. The research community has also shown interest in the outcome. One conclusion is that the marketing of the project has been successful for some of the participants such as the initiator and the residents. The contractor and the consultants are rarely mentioned in articles or reports.

In the working paper *Tvärvetenskaplig analys…* (Boström et al, 2003), the residents and different technologies were studied in more detail. It is obvious that the social and technological components have interacted in the process of constructing these twenty houses, like ANT proposes. The professional actors have tried to influence the outcome by working with many professions, experts in their fields, and trying to improve the technologies if necessary. In the early phases of the process, the actors were able to shape the technology and the system of the buildings. However, the technology and the system did not work as aspired and in the longer run the technology might be more important in influencing the system. Now, the residents are facing an unconventional and, to them, an unknown system which are right inside their lives. Will they manage to influence the technology or will the system shape the actors in the use phase?

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