The implementation process of innovations for energy efficiency – A socio-technical perspective

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Keywords

innovation, implementation, regeneration, housing sector, energy system, socio-technical system, energy efficiency, renewable energy sources, solar energy

Abstract

Goals for energy efficiency in the housing sector have been difficult to implement in Sweden. The increasing demand for energy from dwelling houses is a trend that the national policies are determined to convert into efficient use of energy in buildings and energy supply from renewable sources. How can these goals be met?

This paper focuses on the implementation processes of a solar house concept. Empirical findings from four case studies in Sweden are presented and the forces behind success and failure are analysed. The buildings are presented with a socio-technical perspective involving both technology and human beings in the implementation process of innovations for energy efficiency.

In the first case, the building is a small private office building and the energy system was implemented by the owner with some assistance from researchers at the university. The second case is a regeneration project from the 1980's, which has been described as a successful innovative project, technically and socially. The third case, also a regeneration project, had the aim of lowering energy demand by 40 percent. The fourth case study is in the same area as the third case and with the same goals, but lessons from the third case made the energy system somewhat different. In order to analyse the empirical findings theoretically, concepts from innovation implementation theory and large technical systems are used.

Results from the analyses show how models to describe the dissemination process between different construction projects are incomplete and how theoretical concepts to comprehend disconnection from a large technical system in momentum are missing.

Introduction

In Sweden, the focus on energy in buildings is addressed in various governmental documents. The main tasks described in these documents are how to use energy more efficiently in buildings and how to lower the demand for energy in buildings. In 1996, the new prime minister of Sweden, Göran Persson, stated that "Sweden should be a driving force and a model for ecological sustainability. The wealth should be built on a more efficient use of natural resources – energy, water and raw material" (Swedish Government, 1996). The overall goals are as described in the *Swedish environmental quality objectives* (Swedish Government 1998). The environmental quality objectives consist of 15 different areas to be considered as Sweden moves on into the future. The purpose is to highlight environmental issues and voluntary work in all economic sectors in order to achieve these objectives. Of these 15 objectives, at least 2 have a direct influence on how to consider energy in buildings. These two are: *A good urban environment* and *Limited (influence on) climate change*. In the objective *A good urban environment* it is stated, for example, that the use of energy resources has to be as efficient as possible and the resources used should be renewable.

The housing sector accounts for 40 percent 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 a long-term goal and is supposed to lower the impact on the environment, particularly the climate (Swedish Government 2002: 15). Sweden is said to be a leading country when it comes to energy regulations in national building policies. However, the housing sector is undergoing a change towards being less concerned with saving energy. Some explanations may be found in the fact that the quality of houses is assured by self control and not by local authority officials as was the case previously. Despite the fact that the rules for buildings are still among the strictest in the world, newly built dwellings are less energy efficient today than in the 1980's (Harrysson 1997: 3, Nässén & Holmberg 2005: 1043) .The responsibility for implementing the building policy falls on the building proprietor, the municipality no longer possesses that authority. Internationally, Sweden is no longer a leading nation when it comes to implementing strict policies (Eek 2002: 25f).

In addition, problems in the building sector have been highlighted in public investigations (Building Cost Delegation 2000, Building Commission 2002) as well as several research projects (Björklöf 1986, Anheim 2001, Feminías 2000, Feminías 2004). The sector is among other things criticised for being non-innovative and unable to learn from experience.

Struck with these not very hopeful prerequisites, one must ask: how is it possible to achieve energy efficiency in building projects in Sweden?

In this paper the processes behind four different building projects will be described. The purpose is to analyse the causes of success and failure when implementing technology for energy efficiency in these projects.

Within the scope of the purpose, the focus is on the following questions:

- Which are the important features when implementing energy efficient technology?
- What are the differences between the projects in the planning and building processes?
- Which theoretical perspectives are important in understanding these features?

To fulfil the purpose of this paper, four case studies are presented. The four studies are connected, since traces of the innovative energy system developed in the first case can be found in the other three cases. The expression *solar house concept* is used to describe the interconnected part of the innovation, including solar air collectors and greenhouses. The first two cases are based on descriptions in books and reports and one key informant interview. The third and fourth cases are based on primary sources such as interviews and meeting protocols. The data collected from these sources are used for describing a process, where the story of the innovation and dissemination of an energy system is described. Unfortunately, there are some gaps in the description since only one verbal source has been found to provide a description of the first two cases. This is an on-going research project and the conclusions are therefore preliminary. The time span of this story is from the mid 1970's to the year 2004. This journey will follow the solar house concept in different projects and explore the development of the concept from a socio-technical perspective.

Understanding processes of implementation – a socio-technical perspective

The four case studies of solar houses describe a process of implementation and dissemination of innovations. The concept *implementation* is preferred since it more clearly displays the characteristics of the process (Molina 1997: 602). *Implementation* indicates the mutual process involving both technology and human beings.

IMPLEMENTATION OF INNOVATIONS IN THE BUILDING SECTOR

First it is important to identify the different stages in an implementation chain of innovations in the building sector. The common stages of implementation are presented by Slaughter (2000: 4) as *identification*, *evaluation*, *commitment*, detailed *preparation*, actual *use* and *post-use evaluation* (Fig. 1).

The implementation stages are used to describe innovations in construction, including refurbishment and installations, which are the focus of this paper. In short, *the identification stage* of the implementation circle is where the objectives of a project are specified and alternatives are presented. *The evaluation stage* focuses on the return of the innovation with respect to costs. In the third stage, called *the commitment stage*, the decision to implement an innovation is made official and resources are allocated in order to finalise the project. *The preparation stage* is described as neglected, although important since it is at this stage the stakeholders e.g. owner, designer, general contractor, special contractors are mobilised. It is in *the use stage* that the innovation is adjusted and changed to fit in with the old system. This stage also includes the training and the learning of personnel. In the final stage, focus is on *post-use evaluation* where the essential factor is collection of information about implementation.

The mode of implementation is dependent on the characteristics of the innovation. Slaughter (2000: 8) mentions several types of innovation, ranging from modest improvements to radical innovations. Since the concept *radical innovation* is of most relevance in the selected case studies,

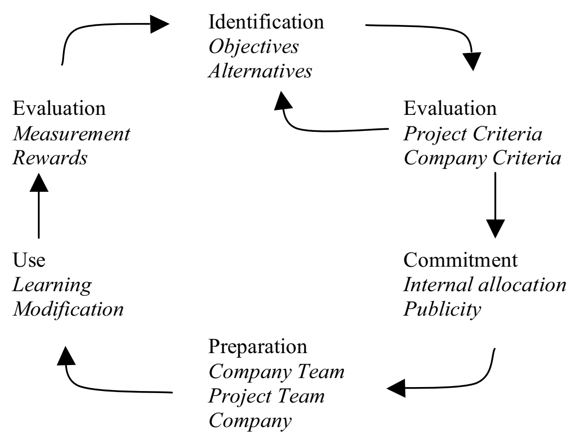

***Fig 1**. Implementation stages for innovations (Slaughter 2000:4).*

it will be described here. The characteristics of radical innovations are that they often stem from research institutions and by a stakeholder that has no vested interests. Slaughter (2000: 13) suggests that the innovation is likely to be decided on before a project is identified and that the evaluation stage is made separate from a project. The stage of commitment probably coincides with feasibility and design studies.

The evaluation of radical innovations is rather special. Since the innovation can be of strategic or social importance, the evaluation must consider the whole system, e.g. the energy system. Included in the evaluation stages is the matter of learning about the technology and involving key personnel in the organisations. Organisations committed to the implementation are likely to benefit from a radical innovation (ibid.). In the following stage of preparation, key competencies are allocated to the implementation. The use stage includes co-ordination of the participating organisations in order to gather information about the operation of the innovation and subsequently to adjust the non-working parts.

How can radical innovations be re-used in other projects by other organisations (Slaughter 2000: 15)? Thus the analysis of implementation should include a *re-use stage*. In this paper the process is perceived as a "spiral" instead of a circle since development of innovations and re-use is necessary in order to facilitate dissemination. In addition, it is necessary to analyse in more depth what happens during the use stage. This stage includes learning and modification, and has been identified as a stage of *innofusion*, which includes inventions, innovations and diffusion of technology described as an extreme non-linear model of innovation (Fleck 1993: 173).

THE SOCIO-TECHNICAL SYSTEM APPROACH

By having a socio-technical perspective, the solar house concept is regarded as a socio-technical system, emphasising the interaction between the technology and the social. Bladh (2003: 3ff) has analysed the socio-technical systems described by Hughes in the much cited work *Networks of Power, the Electrification in Western Society, 1880-1930* (Hughes 1983). Drawing on the work of Constant (1987: 229), one conclusion is that there are three phases of systems in *Networks*. First, is *the electric lighting system* including an inventor like Thomas Edison, in the case described in *Networks*. Second, is the *universal lighting and power system* which includes managers as entrepreneurs. Third, are the *large regional power systems* including important engineers as entrepreneurs. The last two phases include a supportive social environment thus constituting a socio-technical system with momentum i.e. a direction of movement (Bladh 2003: 7).

The concept *radical innovation* is used by Hughes to emphasise the initial invention in the first phase (Hughes 1987: 57). Similar to the concept used to describe implementation in the building sector (see above) radical innovations are initiated by independent actors not tied to organisations in competing fields.

An analysis based on Hughes' theoretical concepts can be criticised for paying too much attention to the micro-level of a system (Sorensen & Levold 1992: 14) and to the individual entrepreneur (Bladh 2003: 14). One possibility is to put less emphasis on successful inventors and instead acknowledge inventors who have failed and described their ideas to others, who could learn from their mistakes (ibid.). In that sense, innovations might be considered as a "collective bank of ideas" consisting of applications for patents and articles in journals. Paying attention to the meso-level is a similar approach. Sorensen & Levold states that there are "very important 'intermediate' institutions and institutional arrangements (networks) involved in technological innovation" (1992: 14). Crucial elements of innovations are *tacit knowledge* among the engineers and *local infrastructure* such as collaborating companies and institutions.

SUBSYSTEMS AND SMALL TECHNICAL SYSTEMS

The energy system of a building comprises both technical and social components. A building is a focal point where energy carriers, including heat and electricity, and energy users, including the demands of occupants and buildings, meet. The owner of a building has to manage the flow in the grids for district heating and electricity, and the demands of users. Thus the socio-technical system consists of energy carriers, grids, technical appliances, owners, occupants, managers etc.. The energy system of these solar houses differs from a common energy system since other appliances, e.g. solar collectors and new social groups, are added. The social groups in these cases are inventors, sociologists and technical researchers.

Starting with Hughes' concept *socio-technical system*, a model of *small technical systems* will be suggested in this chapter. The solar house concept is described as a subsystem of a large technical system aiming at more decoupling from a large technical system. The theory of *large technical systems*, LTS, contains several aspects of the development of a system, including the process from invention, via implementation to momentum (Joerges 1988:10). Included in this process is the scale of the system, going from local, via regional, national, international, to intercontinental. What about small technical systems (Offner 1999: 217)? Will they act in accordance with the theory of LTS? Offner states that "there are very real 'small' technical systems which possess all the characteristics of the large ones, size excepted. Such is the case for a good number of urban technical networks, which have no reason to 'de-urbanize'" (ibid.).

The large technical system which this subsystem is a part of is the district heating system of Gothenburg. The development of another Swedish district heating system has been described in a thesis by Summerton (1992). Although not as large a system as the one described by Hughes, the LTS theory has been used to analyse the process of a relatively minor technical system, i.e. a district heating system. The suggestion in this paper is to perceive the solar house concept as a *subsystem* in the phase of momentum.

Constant (1987: 227) has highlighted the role of the subsystems indicating the hierarchical mode of a system. The conclusion is that whether an innovation is incremental or radical depends on the position of the innovation in the hierarchical system. If a subsystem is faced with a problem, the problem can be solved within the subsystem as long as the interface towards the system as a whole is maintained.

The intention of this chapter was to introduce the concept *small technical system*, referring to a socio-technical system in buildings aiming at independence or "breaking away" from the large technical system in the phase of momentum. This technological impetus indicates a certain direction and speed of development which makes the system difficult to change. The solar house concept might be a pocket of resistance in the sense that it offers an alternative to the heat delivered by the local energy company via the district heating system. A similar approach is presented by Meier (1994: 211). The case of dispersed power production is presented as a support to an existing power system faced with problems of generation and distribution. However, the solar house concept is not supporting a district heating system with problems. Instead, it is a challenger to it.

Solar houses in Gothenburg – four case studies

Four case studies have been selected in order to highlight implementation for energy efficiency. The first case study is a small office building initiated by an architect and a sociologist in the 1970's. The dual aim of this construction project was to heat the house mainly using heat from the sun and to create spaces for social contacts. The second case study has an energy system inspired by the first case. This regeneration project was initiated by the same couple of people in 1983 and the energy system was implemented on a multi-family dwelling house consisting of 24 flats. It was then not until the mid 1990's that another project inspired by the two earlier was launched. As in these earlier projects, the inventors were among the initiators and the energy system included solar heating and spaces for social contact. Targeting dwellings in the "one million homes programme", the housing area Gårdsten became involved, initially with 255 flats, which is subject of the third case study in this paper. A few years later, another 166 flats and the fourth case study, were the object for implementation of a solar energy system. In order to show the implementation stages and how the innofusion process was present, these four cases will be described in more detail.

THE FIRST CASE STUDY – THE INVENTION OF A SOLAR HOUSE CONCEPT

The first case study is based on a small scale project in the mid 1970's. A couple, trained as an architect and a sociologist respectively, bought an old farm estate on the outskirts of Gothenburg, the second largest city in Sweden. During the years as a student in the 1970's, the architect became interested in solar energy in buildings. The source of inspiration came mainly from sunny California and experimental projects. At this time, there was a general awareness of the problems caused by oil dependence. Due to a disastrous fire, a cowshed belonging to the farm estate was destroyed. The cowshed was supposed to be used as an office and the architect decided to rebuild the house in the same place using cheap building materials. The idea of using the sun as a source of heating became a possibility as the materials chosen were suitable for that purpose. Corrugated iron became a multi-purpose material, suitable for load bearing, solar panels to heat the air and channels to distribute the hot air. Another important component of the energy system in the new office building was a special salt, which stores heat. The office was equipped with a greenhouse integrated with the solar energy system of the building. The house was built in 1977 - 1981 (Nordström 1982: 69). The solar air system contributed to the annual heat supply with 50-65 percent (Nordström 1982: 68).

This was a time when nuclear energy became questionable and as Sweden, among other countries, prepared for a referendum to decide upon the future of nuclear energy, people became interested in alternative sources of heating. The solar office became a site where people interested in solar energy could visit to learn more about it. The 1970's was a time when small-scale projects for energy saving were implemented in Sweden, partly since it was possible to apply for financial support from the Building Research Council from the late 1970's until 1990, including this solar office building.

THE SECOND CASE STUDY– THE IMPLEMENTATION OF A SOLAR HOUSE

The solar house in Järnbrott is an example of how the focus on ecological housing changed from small houses to multi-family dwellings during the 1980's (Örneblad 1997: 2f). This solar multi-family house was a refurbishment project where experience from the solar office building was utilised. Originally constructed in the mid 1950's, this house consists of three floors with 24 flats. Researchers from three universities in Sweden used the Järnbrott neighbourhood as a study area in their energy research. The solar house became one part of that research. Initially, the inventors of the solar house concept became involved in an early stage as an expert on solar heated air. This refurbishment project was also partly financed by the Swedish Building Research Council. In the proposal to the research council a greenhouse was included, together with the technical parts of the solar energy system. From his experiences with the office building, the inventors were certain that the greenhouse was a perfect incentive for acceptance and understanding of solar heating, thus the greenhouse has pedagogical value (Nordström 1999: 53).

The purpose of this solar house has been described as consisting of three interconnected parts (Örneblad 1997: 68). Firstly, to develop airborne solar panels suitable for blocks of flats; secondly, to create room for gardening in the greenhouse and as a result develop a sense of community; and thirdly to use the greenhouse as an educational tool to help develop an understanding and acceptance of the solar energy system.

The sociologist and architect couple have been described as the most important actors in this project. They have been the driving force throughout the whole process: from the original idea to the actual building phase. A representative from the construction company commented on the fact that the sociologist as well as the architect was present at the building site almost every day, describing them as "…extremely committed. This kind of commitment is hard to find" (Örneblad 1997: 69).

Among the other professional actors in the process some were especially important like the building proprietor, which was owned by the city of Gothenburg and a department at Chalmers University of Technology. The building proprietor was at the time known as a company that was willing to try new solutions. The aim was to evaluate this experiment and if the purposes were fulfilled, the solutions for heating and sense of community could be transferred to other refurbishment projects (ibid.). The department at Chalmers provided knowledge and assistance during parts of the planning process, especially concerning the building as a system. This department was also responsible for the evaluation of the solar energy system (Gustén & Jagemar 1992: 4).

The project was successful in terms of energy saving and function. The solar house saves 40 percent of bought energy compared to identical refurbished houses without solar heating in the same neighbourhood, of which 40-45 percent was related to the solar heating system. The other half was due to other measures taken, such as insulation and the operating control system. (Gustén & Jagemar 1992: 29) The greenhouse also fulfilled its goals as it was intensively used and appreciated by the residents. A greater sense of community was accomplished according to the interviewees. (Örneblad 1997: 159)

Örneblad has summarised the reasons for the success of the project: There was financial aid from the research council and a driving force in the architect and the sociologist. Also, there was social stability in the neighbourhood and some of the residents became real enthusiasts. The conclusion was that the architecture and the site of the greenhouse have encouraged a sense of community.

Until the publication of the licentiate thesis of Örneblad there were no follow-ups. The reasons for this are explained as (Örneblad 1997: 154): Public means of control to favour environmentally friendly measures were missing. The housing company was reorganised and there was a loss of interest in the project. The social aspects of the project, including the greenhouse, were never evaluated and the results of this dimension were therefore not known. In a ddition, the building sector was sceptical of environmentally friendly buildings.

THE THIRD CASE STUDY –THE IMPLEMENTATION OF A SOLAR HOUSE CONCEPT 2

The solar house of Järnbrott was a success in the eyes of the architect and the sociologist. The energy system developed in the process fulfilled the energy goals and the greenhouse fulfilled the social goals. Accordingly, this concept had to be disseminated. However, not a single project started and the demand for solar houses was non-existent. In 1996, an opportunity opened up as the European Commission launched the fourth frame programme. The inventors joined forces with a Swedish researcher and applied for an experimental project. This was supposed to be a refurbishment project in Gothenburg hosted by a large housing company owned by the municipality. The project received financial support but due to reorganisation within the housing company their interest in carrying out the project diminished. The inventors and the researcher had the choice to either abandon the whole project or go and look for another partner. At the same time, a new housing company was established in the area of Gårdsten and the project was presented to the managing director.

The housing area of Gårdsten is situated on a small mountain 12 kilometres from the city centre of Gothenburg. The area was built during the 1960's and can be described as a large-scale housing area. Gårdsten was a part of a government initiative to build one million new flats in 10 years. This was a result of the housing shortage at the time. Areas with large-scale dwellings from this decade can be found in several Swedish cities and in Gothenburg there are several. The so-called "million homes programme" has a bad reputation and wealthier tenants usually choose not to live in areas such as Gårdsten. The entire stock of flats in Gårdsten has never been fully rented out and low maintenance made the flats poor in standard. This was the place where you were able to find an flat if you were not welcome anywhere else.

The housing company Gårdstensbostäder was established in 1997 and was a union of the flats in Gårdsten owned by two other housing companies. The managing director of the company describes the area as: "discriminated, or as commonly said, segregated".

The main task for the new company and the managing director was to *develop* the area. Being a company owned by the municipality, there were certain obligations attached to this task. The managing director describes the company as having a greater responsibility to the residents and to society. As the inventors and the researcher approached Gårdstensbostäder with the project of turning some of the blocks of flats into "solar houses" the managing director saw the project as fitting for the goals of the newly established company.

The idea was to combine conventional energy-efficient measures with more unconventional technologies like active solar energy. One of the main tasks was also to involve the residents in the changes in the area and allow them to be involved in making decisions about their flats and the surroundings. This was a process which needed special dedication, thus the housing company hired a person recently graduated from the university. Her task was to *mobilise* the occupants in the area, and establish trust between the new organisation and the residents.

In Gårdsten the aim of the project became "to demonstrate a comprehensive integrated renovation concept, comprising energy conservation and utilisation of solar energy, as well as improved architectural and social conditions, making the blocks of flats in a typical existing residential area from the 70's more attractive." (Dalenbäck & Nordström, 2001) The important installed technologies of the energy system were: insulation (gable ends and roofs), glazed balconies, roof integrated solar collectors, new low-emission panes, individual metering of heating, hot water, cold water and electricity, new energy efficient cookers and refrigerators , wall integrated solar air collectors (one block) and solar heated double envelop (one block). The refurbishment project also included greenhouses integrated in two blocks.

The results from the technical evaluation shows a 40 percent savings for heating, ventilation and domestic hot water (Dalenbäck & Nordström 2001). Gårdsten had become a more attractive place to live after the refurbishments. However, only ten blocks with 255 flats were refurbished initially.

The most unconventional technology used in the area was the wall integrated solar air collectors on the wall facing south and the double envelope on the walls to the east, west and north. This was described as an "innovative technology" by the newsletter from the European Commission. Another innovative measure was the glazing of the already existing balconies. In these balconies the incoming air is pre-heated and used in the flats (ibid.).

THE FOURTH CASE STUDY – THE SOLAR HOUSE CONCEPT IS DISINTEGRATED

Another 8 blocks with 166 flats were refurbished in Gårdsten during 2001-2004, but this time neither the greenhouses, the solar heated double envelope nor the wall integrated solar air collectors were installed (RegenLink 2000). The inventors, who had been the link between all previous projects, were also excluded. The European Commission partly financed this project within the Regen Link programme.

One aim of this project was to learn from experiences with the first solar houses in Gårdsten and to do things better the next time. In terms of the outcome of this solar house project, the most important experience for the housing company was to lower the costs of the refurbishment by being a more demanding building proprietor. This includes being in control throughout the whole process. During the initial project trust was established between the people representing the housing company and the occupants, which was consolidated by the introduction of house managers locally. One of the things not implemented in these 8 blocks was the greenhouses. One reason was because it did not benefit the occupants. One factor considered as beneficial to the occupants was the individual metering, allowing all households to pay individually for heating, electricity, and hot and cold water. All these services had previously been included in the rent and paid for collectively.

None of the original parts of the solar house concept were installed in this case. Only solar collectors on the roofs and glazed balconies, apart from the more conventional measures like insulation, were included. As other parts of the housing area were refurbished only the individual metering was installed in these flats, apart from conventional measures.

The implementation process

According to the model of implementation suggested by Slaughter (2000), innovations can be analysed as different phases of a process (see Fig. 1). Here the phases in the four case studies will be compared in order to analyse the differences between the implementation of solar house concepts. An analysis on the meso-level will be presented and the concept *small technical system* is further explored.

THE SOLAR HOUSE CONCEPT AS A RADICAL INNOVATION

In the case of the office building, the process was loaded with radical innovations. Since this was a construction project, it was rather flexible in terms of architecture and choices of material. Besides, the work was mainly carried out by the owners not involving too many people. In this paper it is argued that the solar house concept was invented in this project, but it must be emphasised that the concept was inspired by several other projects, primarily from other countries. The idea of using the greenhouse partly as a space for social contact and partly for educational purposes was discovered during the use phase. Similar to the content of the use stage concept introduced by Slaughter, other people will learn about the innovation at this stage. As this house was the destination of field trips for curious people, the ideas were disseminated via visitors. Also, the architect wrote a report describing the process of this invention. In that sense, the inventor was also the evaluator, diminishing the value of the evaluation.

The following projects described in this paper were also initiated by the inventors, but this time it was a refurbishment project. Several aspects of the solar house concept were decided upon before the actual building was chosen. A consequence of this approach was that some stakeholders had to be persuaded about some of the ingredients. This was true for the relationship with the occupants. The refurbishment and the solar heat system were accepted but initially, the greenhouse was the subject of conflict between the occupants. The dispute was not solved by the time of the reconstruction. A small group among the occupants started to use the greenhouse as it was finished. In time, the majority of residents became involved in the cultivation activities in the greenhouse and the aim of increasing the areas available for social contact between the tenants was achieved. The refurbishment was completed in 1986.

For almost ten years, there were no follow-ups to the multi-family solar house. Several explanations have been suggested above. Among the reasons was the fact that it took until 1992 before a technical evaluation was presented (Gustén & Jagemar 1992) and until 1997 before the social aspects of the concept were analysed (Örneblad 1997). Information about experiences from the implementation process was most certainly lost during the years between implementation and evaluation. However, the initiators continued to believe in the idea, and without this engagement it could have been the end of the story of the solar house concept.

Since the opportunities to get funding for experimental buildings nationally had diminished, an application to the European Commission seemed like a good option. Being among the lucky few in the selection process for financial support from the EC, the concept got another chance.

This time, the planned concept was developed with another housing company to suit the needs of the houses to be refurbished. However, since this housing company had second thoughts and left the project, another object on which to implement the concept had to be found. The new objects were found, and the objective of the project was altered. This time the renovation process had to be carried out in cooperation with the occupants and the technology installed had to gain these tenants' approval. Now the main aim was to strengthen the individual households. Although the occupants became involved in the planning process and decided upon several aspects of the refurbishment, they had no influence over the implementation of the solar house concept. There were no alternatives.

In the concepts suggested by Slaughter, the users of the buildings were excluded. The implementation stages only include personnel. This is a major flaw in the model for implementation in dwellings since the occupants also will be a part of the implementation process.

An evaluation of the implementation model suggests that the model is very close to a linear process and it is stated that "most implementation processes may proceed through each of the stages" (Slaughter 2000: 4). In conventional building processes, that is usually the case. In this paper, it has been suggested that the process should be regarded as a spiral, connecting new projects to older ones. Experience learned in one project will be used as input in a second project. These cases are examples of how inventors were the connection between projects. In other cases the housing company might be the connection.

Instead of a linear process, these case studies generate examples of how a radical innovation was implemented as a process of *innofusion* with extreme non-linear processes (Fleck 1993: 173). Such processes are characterised by "internal learning" during the implementation. During the use phase important aspects not foreseen will be discovered and incorporated into the concept. In the last case study the solar house concept was disintegrated and unique parts, such as the double envelope and the greenhouses, disappeared. This was an effect of learning on the part of the housing company. During the implementation in the third case study, it was discovered that the greenhouses did not fulfil the same objectives as in the former projects. As a consequence, the greenhouses were not implemented in this project.

The building sector faces several obstacles for implementing innovations, one of the most important being the *project*. The organisation during the planning and building process is temporary. One consequence of this form of organisation is that every project is implemented from the beginning of the circle. Much of the experience from previous projects is "tacit knowledge" embodied in individuals; documents describing processes and experiences are rare, at least among the building proprietors. Since the sector, as a whole, consists of non-writers and non-readers, the ability to spread experience and knowledge via written texts is also limited (Björklöf 1986: 164).

FOCUS ON THE MESO-LEVEL

Inspired by the theory of large technical systems, much attention has so far been paid to inventor-entrepreneurs. Due to the criticism of this theory from Bladh (2003) and Sorensen & Levold (2000), an additional interpretation will be presented which is focused on the meso-level. Examples from Gårdsten will be used.

The reason why Gårdstensbostäder was established has been explained by the head of the group of companies to which Gårdstensbostäder belongs: "The area was becoming ghettoised". For a company established and owned by the municipality the responsibility stretches beyond providing flats for rent. A long term goal might be to develop the area socially, economically and ecologically, thus fulfilling the goals for sustainability on the local level. It is not determined that a solar house concept is included in such a development; other energy systems might fit the objectives equally good. In this case, individual metering and billing proved good enough.

In the description of Edison and electrification, supportive institutional systems were established, among them the establishment of higher education for electro-technology (Bladh 2003: 7). Additionally important were the number of new companies. District heating in Sweden is a socio-technical system usually with strong connections to the municipality; grids and utilities are publicly owned companies. In Gothenburg, the district heating system covers 90 percent of all dwelling houses and part of the incomes from selling energy is used in the public sector. In the case of solar heating, the system is small, integrated in the building and owned by the housing company. The expertise of a housing company is seldom focused on solar energy. The number and size of companies depending on sustaining solar air systems are small. Thus the social system for a solar house concept is underdeveloped.

A SMALL TECHNICAL SYSTEM

It is when the existing system is challenged by alternatives that the system looks for its boundaries (Bladh 2003: 19). The solar house concept was invented by people not within either the traditional housing market or the conventional energy market. For radical innovations, that is usually an advantage for further development. In the cases of solar house concept implementation, an alternative supply of energy was suggested. The large technical system that was challenged, the district heating system in Gothenburg, is in a state of momentum, where these systems "have a mass of technical and organisational components; they possess direction, or goals; and they display a rate of growth rate velocity" (Hughes 1987: 76). What does the socio-technical system in its phase of momentum include? The vested interests in momentum are immense. Individuals, such as researchers, investors and politicians, along side organisations such as educational institutes, banks and local authorities, are all interested in the maintenance and growth of the system (ibid.). Furthermore, district heating is *tightly coupled* to the local arena since the use of heating in the buildings connected to the grid is necessary in order to achieve a high level of efficiency (Kaijser 1994: 52f).

In these cases, the small technical system was hardly any threat to the large technical system. A system in the phase of momentum is described as *closed* and "not subject to influence from external factors or from the environment" (Hughes 1987: 79). If there are components that are not included, the system acts determined to involve these components. Still, the advocators of the solar house concept managed to implement the system with no resistance from the system builders. The question is how to theoretically explain parts of a large technical system that intend to break away?

A SOCIO-TECHNICAL SYSTEM?

The fact that the solar house concept mixed the social system, i.e. the greenhouses, with the technical, i.e. the solar heat system, has been criticised by one of the evaluators of the technology. It is stated that there was no such thing as a solar house concept since the social dimension and the technical dimension were not interconnected and mutually dependent. Instead, it was important to acknowledge where the boundary of the technical system was and the greenhouse was not within that boundary. However, in the original concept the greenhouse was an integrated component in the technical energy system. In Järnbrott it was never connected to the energy system but integrated in the architecture of the building. In Gårdsten, the solar air collectors and the greenhouses were installed in different building without any connection, except that the occupants have access to the cultivations in the greenhouses. A conclusion with respect to this criticism is that the solar house concept became more and more disintegrated along the way.

Conclusions

In order to fulfil the Swedish government's ambitious energy efficiency goals, it is necessary to make use of the knowledge obtained during the years of experiments and innovations regarding, for example, solar energy. In the empirical findings on the solar house concept it is obvious that the components as well as the concepts are changed in a process of innofusion. During the planning and building processes the innovative technology is shaped by the architects, consultants on heating installations, and constructions workers etc. To be able to learn from these processes they must be described in detail and evaluated. Innovations in construction are more difficult to evaluate than other processes since the users in the planning and building processes are only part of the innofusion for a short period of time. Later, it is the occupants who are faced with the technology and shape the technology. Although important, the perspectives of the end-users, i.e. the occupants, have not been stressed in this paper. As a researcher who focuses on the social processes of a socio-technical system, it is irritating to see how neglected the social dimension is in the evaluation stages. This is especially true since these projects partly aim to create areas that encourage social contacts. One reason may be the distinction between a "technical system" and a "social system", expressed by one of the evaluators of the technology used in the solar house concept. The technical energy system seems as the obvious target for evaluations.

Implementation of innovations in the building sector has a stage of preparation which has been described as neglected (Slaughter 2000: 6). However, this critical stage includes an important learning feature which has been acknowledged in the various cases. When planning the solar house in Järnbrott and the first solar house area in Gårdsten, the importance of including occupants in the planning process was highlighted. This part of the projects has been described as a source of success by the informants.

What is a successful implementation of innovations in the building sector? Is it implementation in one project, or two or more? The answer is probably that it takes more than a few demonstration projects before an innovation is considered successful. The solar house concept in Gårdsten was greatly dependent on actors as driving forces behind the implementation and funding from national and EC programmes. There are however several lessons that have been learned from the processes of implementing the concept. It is not a big risk for a housing company to install innovative technology in one or a few houses. It does not mean that other parts of the housing stock are affected by the action taken. Instead, implementing a solar house concept in one house attracts attention from the media and stakeholders in the building sector. If the concept does not fulfil the aims of the actors, it will not be repeated. However, other innovations may come out of the process. The concept innofusion describes how innovation is done during the phase of dissemination. The double envelope and the greenhouse in the solar house concept inspired the technical solution of the glazed balconies in Gårdsten, which was implemented in the last case study.

The spiral shape of the implementation stage has been an important visualisation of how learning is achieved regarding the solar house concept: how the concept has been invented in one case and disseminated to two other cases and disintegrated in the last case. Experiences from the first case of the small office building were considered in the second case. As the inventors were in charge of the solar energy system and the greenhouse construction in Järnbrott, knowledge was mainly transferred orally. Thereby, the barrier that written texts create in the building sector was surmountable. A similar scenario appeared in the first solar house area in Gårdsten. In the last case, no building was suitable for the double envelope and since the greenhouses did not fulfil their purpose, they were also excluded. These were the experiences gained by the housing company.

The district heating system in Gothenburg is expanding: new housing areas are connected and a new combined heating and power plant is under construction. The implementation of a solar house concept in a couple of hundred flats was not considered as a threat and the interface towards the larger system was maintained. A reason for success in the development of large technical systems can be explained by the number and size of companies integrated in the system. Solar energy systems lack a similar support.

In this paper, the concept *small technical system* has been suggested to point out decentralised systems with the aim of providing an alternative to a system in the phase of momentum, e.g. the district heating system of Gothenburg. It is possible to state that many district heating systems in Sweden are monopolies, especially in the heating market for multi-family dwelling houses. Partly disconnecting a housing area from the system must be viewed as a radical move. The common development is instead to connect areas previously not profitable to the local energy company, e.g. suburbs with single family houses. Concepts to describe a decentralised energy system inside a large technical system in momentum are lacking and need to be developed.

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Acknowledgements

The author gratefully acknowledges financial support from the Energy Systems Program and administrative assistance from the graduate school at the Department of Technology and Social Change and valuable comments from Mats Bladh.