Large scale pilot project with solar heating for a residential area – success and disaster

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Abstract
This paper describes a socio-technical study of a heating pilot plant outside Stockholm, Sweden. The aim is to investigate discrepancies between technical and social evaluations.

The residential area comprises 50 units built in 2000-2001. The low temperature heating system consists of a large solar collector area and a borehole storage in rock with individual electrical backup systems. This is the first project combining solar collectors with borehole storage in rock. The solar energy is expected to cover 70 percent of the total heat demand for hot water and space heating. The project has faced several problems along the process; contaminated soil, faulty valves, exploding pipes and leakages. As a result, the need of electricity for heating has not decreased as much as expected by the inhabitants. Still, the residents are positive to the technology *itself*. It is being perceived as 'natural' and 'clean'. The technical evaluation shows an obvious supply of heat from the solar heating system, while the residents are disappointed in the amount of 'free' energy. Technically, a borehole storage will be in full operation after three to five years due to substantial losses to the surroundings. However, this has not successfully been communicated to the residents. Furthermore, the guarantee period is unclear, due to the reparations, which causes worries about the future. The results of this study are to be useful in the future building of new kinds of energy systems.

The residential area Anneberg
During 2000 and 2001 a new residential area, Anneberg, was erected outside Stockholm, in Sweden. The heating system in the area comprises a large-scale solar collector system in combination with a seasonal heat storage in rock. The solar heat is expected to cover 70 percent of the total demand for space heating and tap water in the area. Both solar heating and seasonal heat stores in rock are well developed techniques, while the combination is unique. When building the area, the solar heating system in Anneberg was part of the EU THERMIE project "Large-Scale Solar Heating Systems for Housing Developments" (REB/0061/97). It comprises a total of seven pilot plants utilizing new solar technology in the Netherlands, Austria, Italy, Germany and Sweden.

The residential area comprises 50 apartments; 18 semi-detached houses and two terraced houses with seven apartments each, occupied since 2001 and 2002. The construction of the houses, regarding insulation, is normal compared to other detached houses build in the same period and the estimated total annual heat demand in the area is 550 MWh or in average 11 000 kWh per year and residential unit (Dalenbäck, 2002). The area is divided into sub units of two, four or seven apartments sharing a short-term heat store and a heat distribution system. Moreover, every apartment has its own hot water tank and floor heating systems, both including electrical backup heaters. Electricity for heating is bought by the individual house owners[1] and electricity supplier can therefore be chosen independently.

1. According to the Swedish Energy Agency (2006) the electricity price for Swedish homeowners in January 2006 was about 0.12-0.15 Euro per kWh depending on

The solar heating system consists of 2 400 square meters roof-integrated ordinary flat plate solar collectors. All buildings have increased roof areas towards south covered by 40 to 65 square meters solar collectors per apartment. The tilt of the collectors is 15, 31 or 37 degrees depending on the roof inclination. The large solar collector area means overproduction of heat during summer. Excess heat is transported, via the sub units, to the borehole storage. The store consists of 100 boreholes with double U-tubes serving as a heat exchanger. The 65 meters deep boreholes penetrate a 60 000 m3 rock volume. The losses from the store are estimated to 40 to 50 percent, but will be even larger the first years of operation. A borehole storage will reach equilibrium after three to five years of operation, when the initial losses to the surroundings have been covered. Solar heat will however both be directly delivered to the households and a smaller fraction indirectly via the borehole storage even before reaching full capacity, but with higher losses. At equilibrium the temperature of the rock will vary between 25 °C in spring, when all available heat has been discharged, and 45 °C in autumn, when the store is fully charged. To maximize the utilization of both direct and stored solar heat a water-based low temperature floor heating system is used to heat the buildings. To enable technical evaluation temperatures and heat carrier flows in the system are measured continuously.

The additional cost for the solar heating system with seasonal storage compared to a conventional heating system was about 1.2 million Euro or 24 000 Euro per residential unit (Dalenbäck, 2003). Subsidies for the project were however given both from the European Commission and the Swedish Energy Agency, a total of somewhat more than 0.3 million Euro.

During the guarantee period, which was intended to be the first two years of operation, the property developer will be responsible for the operation and control of the heating system. After that the tenant-owner's association will take over the operation (Dalenbäck, 2002).

Socio-technical evaluation

Success is defined from certain perspectives and preferences. In the following sections several important issues discerned in the study of Anneberg (see for example Jonsson et al, 2005) are discussed both from a technical and social point of view.

WHAT IS BEING BOUGHT?

Even though a special heating system with solar collectors combined with a bedrock storage was also bought when buying the tenant-ownership, the perception of what kind of heating system is bought and owned varies between households. Therefore, the expectations on the heating system are disparate. While some households see the system as an ecological pilot project, expecting some initial problems concerning its function, others state that they have bought a system that foremost should be economically profitable. Although all of the households included in the study state that they were promised low costs for heating by the property developer, the interviewees also consider the area an ecological investment with a pronounced environmental profile. Different households seem to have let different reasons concerning the heating system carry different weight when buying the tenant-ownership. Those with a more pronounced ecological interest have taken note of arguments concerning environmental issues, while households mainly interested in economy seem to have taken note of arguments concerning the expected reduction in heating costs. There is also a noticeable difference between the households concerning the amount of engagement expected as residents of the area. While some believe that they have bought an accommodation that will reduce the maintenance work, others expected a certain amount of extra work due to the area being a pilot project. This can be connected with the households' previous living environments. Those who moved from a larger detached house believe that this heating system will demand a minimum of maintenance work and engagement from their part. Those who moved from a rented flat are of opposite opinion, meaning that it is a pilot project that they are willing to test and that it might be lacking in functionality at first, with their own inconvenience as a consequence. Interesting to notice is that the expectations concerning the amount of engagement have been fulfilled while the expectations of low heating costs concerning the electrical backup system have not yet been fulfilled.

UNDERSTANDING THE SYSTEM – WHAT'S TO BLAME?

We can establish that the solar heating technology is rather complicated to understand in detail, even though the households seem to have an overall understanding of the technical principles. Furthermore, many of the interviewees view the solar collectors as objects that are just there. They have become self-evident and their purpose is associated with their appearance.

To make the use of solar energy visible a display has been placed on the main heat distribution and control building. The solar power charging and discharging the borehole storage, as well as the solar radiation and ambient temperature, can be read from the display. The solar heating system is also a commonly discussed topic in the news-letter distributed to all residents by the board of the tenant-owner's association.

Before putting all solar collectors into operation, one part of the collector system was tested in spring 2002. After a short period of operation a pipe in one of the collector circuits exploded and caused water leakages in the sub unit. This was due to a faulty valve; the solar collector was not cooled and the pressure in the pipe increased. The pipe cracked before the security valve was activated due to the high pressure. Usually, all pipes in a solar circuit are made of copper, but in this case the ground placed pipes were made of plastic. All the plastic pipes in the solar collector circuits thereby had to be replaced by copper pipes during summer 2002 and the heating system could not be taken into full operation until autumn 2002. If the faulty pipes had not been discovered a power failure during summer could have caused damage in all solar collector circuits later on. At this stage the pipes could be replaced without causing significant damage. However, several residents experienced this incident as being very dramatic. It may have caused reduced trust not only in the heating system, but also in the property developer and its capability. The relatively small damage and that the problem was taken care of does not seem to have influenced the attitude to the incident. Furthermore, the residents

the annual electricity demand.

have several different opinions about what really happened. It is however clear that the incident was highly unexpected.

The problems with the heating system experienced by the residents have been largely perceived as being due to the solar collectors malfunctioning. When a system is not working properly and the residents know that the system is being repaired without having sufficient information on what is malfunctioning in the system this, naturally, gives rise to speculations. However, the solar collectors have been working properly; it is mainly other parts of the system that have caused problems. One conclusion is that what differs the most from previous living environments concerning the heating system is what gives rise to the largest amount of reflection and sometimes also strong emotions. These are the technical room, the floor heating and also to a certain extent the solar collectors. Interesting to note is that the windows, which are energy efficient three pane windows, in general do not give rise to the same feelings. Instead, these are considered to be normal and something that the residents do not take notice of or reflect about.

In late autumn 2004, when the solar heating system had been running without major problems for two years, leakage was found in the heating system. It was located to the borehole storage. First only parts of the storage were disconnected from the heat distribution system, but when finding that the U-tubes had an inappropriate construction causing cracking and thereby leakage, all tubes were replaced (Dalenbäck, 2006). This was done during summer 2005 and the storage was put back into operation in autumn 2005. This resulted in less ability to utilize solar energy stored from summer 2004 as well as excess heat generated in 2005. Solar energy could, however, still be directly used for hot water heating, but could not be stored for the cold season.

On the whole, the heating system has turned out to be complicated to understand. None of the households tactically use water at special hours in order to use the solar heat to its maximum. In general, it is obvious that the households do not have knowledge of how to use the heating system in an optimal way.

HELPLESSNESS – SLOW INTERACTION WITH THE SYSTEM

The heating system, and particularly the floor heating, is considered unreliable and difficult to control by some residents, and gives rise to feelings of powerlessness. The so-called technical room is likened to a nuclear power plant with different experts coming and going (Löfström, 2006). In this case we might speculate about whether this is associated with some form of fear of having a heating system but being unable to fully understand or control it. A fear of future catastrophes is close at hand. One household even provides the floor heating with a personality, referring to it as ”that bastard”, thus bearing witness to the feeling that the heating system does not do what it is expected to. Several interviewed residents also mentioned the slow reaction of the heating system. This may be connected to the residents sometimes complaining about too low indoor temperatures. The property developer, on the other hand, claims that the heating system works properly. However, several residents have experienced cold floors. The floor heating is aesthetically pleasing to some of the households, but was not used as an argument in advertising the tenant-ownerships. However, the floor heating itself *feels different* to regular heating from radiators (Löfström, 2006). A low-temperature floor heating system reacts slower than radiators, since first a large floor volume must be heated before the temperature in the room is increased, causing a delay in terms of time. Furthermore, the temperature difference between the floor and the indoor air is small. The floor will therefore not feel warm. These aspects may have contributed to the indoor temperature sometimes being considered too low. In part, the expectations on warm floors do contribute to the residents experiencing problems with cold indoor climate, but it is not the only factor. There have been problems with some individual floor heating pipes, a problem that has now been attended to.

The technical room is perceived as something for the experts to use and the households themselves use it for well known everyday purposes. One possible interpretation of the fact that it is being used as a storage space for shoes and wood is that the residents are making some kind of protest against the technology. Although some residents have used the regulators to control the heating system they have stopped using them after reaching the conclusion that it is more or less meaningless. The possibility to affect the system is almost non-existent. This lack of interaction might also be seen as a silent protest against the technology.

It is also noticeable that the households do not perceive any need to change their own activity patterns in order to save energy. However, they consider the electricity use being too excessive due to the system not meeting the expectations. The amount of energy used is strongly associated with the technology, resulting in the household activities being seen as a non-causative factor. However, this does not mean that the households are lacking in awareness of the connection between the amount of energy used and their own behaviour. Many households are showing a considerable degree of consciousness concerning this issue.

Technically, when studying measurements of energy flows in the heating system, an obvious supply of solar heat is observed. In Lundh et al (2005) a technical evaluation was done. It was found that the measured storage discharge was 86 MWh from March to December 2003. This equals an average supply of 1 700 kWh per apartment. Another 90 MWh or 1 800 kWh per apartment was directly delivered by the solar heating system during summer, which means a total average solar energy contribution of about 3 500 kWh per apartment and year. Compared to the expected supply of 9 000 kWh per apartment after five years of operation this is a significant contribution.

The engagement in the tenant-owners’ association varies greatly between households. Some work several hours a week with the association while others only read the news-letter. Nevertheless, the ongoing dispute with the property developer, where economical compensation is claimed due to high heating costs, seems to be an important issue for all the interviewees. This is something the households talk about, hence creating an important object in their everyday lives. The dispute itself is seen as mainly economical, but the heating system and its future function are also considered important aspects. It would be interesting in future studies to follow up on the legal process and also to investigate the consequences of and reasons behind the fact that the minutes from the tenant-owners’ board meetings are kept secret even from its own members. This is not, however, part of this study. To follow up the technical performance after five years of continuous operation, to investigate if the solar heating at that time can cover the expected 70 percent of the demand, would also be highly interesting.

Lessons to be learned

According to the feasibility study, Lundin et al (1998), the borehole storage will reach full capacity after three to five years. Consequently, this was a well-known fact before erecting the heating system. This information does not, however, seem to have been properly transferred to the residents. Several interviewed residents expected an optimally working solar heating system after only one year of operation. Exactly what information that was spread to the residents is not known by the authors, but a misunderstanding due to lack of information is obvious. Disappointment and claims on financial compensation for the high electricity costs could perhaps have been avoided by better and clearer information.

The interviewed households present a wide array of reasons concerning the choices, the use of, values and attitudes concerning the heating system of Anneberg. Even though economic issues together with ecological ones are important factors, it is still the *functionality* and *comfort* that are of greatest importance to the households. It is important to note that the strongest reactions do not seem to be connected to high heating costs, but rather to the lack of functionality of the heating system. Even though the indignation among the interviewees is obvious, the attitudes toward the overall *concept* of the new heating system are on the whole positive. Solar heating is described as a "clean technology" and its positive environmental aspects are accentuated. In situations when the system needs to be adjusted and repaired it is clear from our study that information and communication is crucial for the residents' trust in the heating system as a whole to be maintained. Otherwise, the blame is put on the technology that visually differ the most from traditional heating systems, i.e. the new technology itself and in this case the floor heating and the solar collectors. This is, of course, negative if new technologies with renewable energy sources are to be tried in the future.

The positive attitude towards the overall concept of the heating system is remarkable considering the fact that the heating system has not yet been proven to be as effective as expected. The residents have both had considerable *discomfort* with too low indoor temperatures and high electricity costs due to the *low-functioning* of the heating system. The electrical backup heating system has, in practice, been the main heating system of the area so far[2]. This could at least partly be explained by the overall positive view amongst the residents concerning what they describe as "natural energy", a view that is so strong that even a low-functioning system is a positive one. The households remain positive to the overall concept and remain confident that it will work, eventually.

Furthermore, the property developer will run the heating system during the guarantee period, but is not willing to continue the operation after that. They claim that the system will work properly, but do not want the responsibility, even though the tenant-owner's association is willing to pay for the service. The residents and the property developer are currently discussing the future operation of the project and the discussions are mainly focused on when the heating system should be considered as fully functioning and the guarantee period as being over.

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Conclusions

The pilot project in Anneberg can, as discussed in this paper, be considered both a success and disaster depending on what perspectives are chosen when looking at the results. Technically, solar heat has been supplied to the households and the system principle is obviously working, although not yet as efficient as expected. Thereby, the project can be regarded a technical success to demonstrate a new type of energy system. On the other hand, the residents are not satisfied; the indoor temperature has sometimes been lower than desired and the confidence in the property developer and the heating system itself often lacks due to recurring breakdowns and repairs. Accordingly, the system can be considered a disaster. Still, the residents are hopeful and believe in the technique and the value of demonstration; they are proud of their clean heating system. Thus, Anneberg can be considered both a success and a disaster depending on what methods of measure are used. Irrespective of its technical and informational successes and disasters it has proven to be highly instructive and demonstrative for testing how new technology should and should not be introduced in residents' daily lives. The key element is, according to this study, that information and discussion with the users of the system, i.e. the residents of the area, and what can be expected and not, needs to be well thought-through and sufficient resources to do so must be included in the budget when building future pilot projects. The users also need to be given the proper tools – technical as well as educational – to control their own indoor environment; but it is also important that the users are given the correct information concerning what they will be able to control and not.

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