SINTEF Building and Infrastructure

RUTH WOODS AND ERICA LÖFSTRÖM

User Evaluation Report

What have we Learned? The Advantages and Barriers for Successful Participation in the ECO-City Project

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1 Preface

This report is a contribution to the EU-project ECO-City – Joint ECO-City developments in Scandinavia and Spain www.ecocity-project.eu . The objectives of the "ECO-City Development Project" are to establish a technological basis for and to demonstrate innovative integrated energy concepts in the supply and demand side in three communities in Denmark/Sweden, Spain and Norway, all of which have an advanced energy profile. The instigated activities and technological installations are based on both the demand (ECO-buildings/RUE) and the supply side (RES). In addition the project is working with a "Whole Community Design Approach" in order to ensure the largest energy saving potential, and to ensure coherence in all activities.

This is the background for the ambitions associated with the ECO-City project, and the technical installations which were installed. At the end of the project period it was relevant to consider energy savings which are a result of ECO-City and to analyse the actual impact of the technical installations. It is also important to consider what we has been learned through operation and participation by the end-user group during the project period, and this is the final aspect which is central in this report.

ECO-City Trondheim is the focus of this report. The intention is to present what has been learned from a user-evaluation of the technical installations in each of the 13 pilot projects, as well as analysing the impact on a community level within the city of Trondheim. The analysis will also consider the advantages and barriers associated with the different technological installations.

Thank you to everyone who has participated in making this report possible. This includes the four organisations, Trondheim Municipality, TOBB, Statkraft varme and Heimdal Bolig AS, and in particular the project managers, technicians, caretakers and others involved the 13 pilot projects. The insight provided by those who participated in interviews and willingly shared information about the projects and the results was invaluable. Thank you also to COWI who were responsible for the project management of the whole ECO-City project.

Trondheim, November 2012, Ruth Woods

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2 Introduction

2.1 ECO-City

This report is a contribution to the EU-project ECO-City. The scientific and technological objectives of the ECO-City project are to establish a technological basis for, and to demonstrate innovative integrated energy concepts in the supply and demand side in three communities in Denmark/Sweden, Spain and Norway, all of which have an advanced energy profile. The aim within the communities of Helsingborg/Helsingør in Sweden and Denmark, Tudela in Spain and Trondheim in Norway was to reduce the demand for heating, cooling, electricity and ventilation, and to supply the necessary heating cooling, electricity and ventilation in the most energy efficient way.

A central thesis within the ECO-City project is that it is not sufficient to look at one eco-building settlement alone, because there is a need for a renewable energy supply on a community level. The project therefore encourages energy savings in buildings and eco-buildings, with the aim of achieving an optimal and cost-effective reduction of energy consumption. The next step towards energy efficiency is on the supply level using several energy sources, which are chosen in relation to what is potentially the most economic mix in each community.

The city of Trondheim is the third largest city in Norway, with a population of 177,258. It is located on the banks of the Trondheimsfjord, in central Norway and is the administrative centre for the county of South Trøndelag. The climate in Trondheim is predominantly an oceanic climate because of the location close to the fjord, but it also boarders on a humid continental and subarctic climate, and winters can have subarctic temperatures. Eco-City Trondheim within the parameters provided by the Norwegian climate has influenced energy consumption within 2,100 dwellings through direction intervention in 13 pilot projects. This has been done through increased use and improved utilisation of RES in the district heating supply, innovative eco-building principles in new buildings and rehabilitation projects, and reduced energy consumption through the implementation of intelligent metering and monitoring systems. The project also proposes training and dissemination involving end-users on more than one level. Key innovative technological developments are:

- Polygeneration using adsorption/absorption cycles for cooling and heating.
- Innovative energy metering and control systems
- Eco-supply of a large hospital using polygen combi absorption cooling
- Energy storage, for example seasonal storage of waste

This report is an evaluation the 13 pilot projects that are part of ECO-City Trondheim from the standpoint of the end-users associated with the projects. The report considers what we have learned and aims to provide clarity in relation to the advantages and barriers associated with the individual projects.

2.2 A User Evaluation Report

The original intention of this report was to look at all levels where there has been a degree of user-intervention; a report of this kind would require interviews with residents in the housing projects and with private individuals using the municipal buildings in Trondheim. Access to this kind of information is strictly regulated by the Norwegian Data Inspectorate who has chosen NSD (Norwegian Social Science Data Services) as its partner for implementation of the statutory data privacy requirements in the research community. The original ECO-City project did not apply to NSD for this kind of data access and the timeframe associated with the user-evaluation report meant that it was too late to apply for access. This limitation has provided the parameters for who "the end-user" is in this user-evaluation. The end-users have in this report therefore a professional relationship with the 13 pilot projects. They are either involved in the project management and development, or with the day to day operation of the technical installations.

The report will consider, from the end-user stand-point what has been learned in relation to each of the 13 pilot projects, as well as analysing the impact on a community level within the city of Trondheim. The potential impacts and actual impacts of the wider ECO-City project have been considered and monitored to varying degrees during the whole project period. At the start of ECO-City the independent University of Magdeburg investigated the barriers, trends and needs, for end-users on a European level. In addition a central aspect of the project has been the development of energy metering and control. One of the aims of the energy metering system is to provide information that the user-end can understand and relate to, and at the same time provide the necessary information for the facility managers. It was proposed in the initial "Description of Work" that the involvement of the end-user was expected to have a large impact on energy savings. This rapport provides a presentation of the technical systems during operation and analysis of the impact on the end-users in the 13 projects in Trondheim. Moreover, it provides an analysis of the advantages and barriers associated with the different technological installations in relation to both the rational use of energy (RUE) and renewable energy supply (RES).

The report is based on a qualitative study involving a broad cross section of the end-user group which took place in Trondheim in the autumn 2012. ECO-City in Trondheim involves 4 separate organisations, Trondheim Municipality, TOBB (Housing cooperatives), Heimdalgruppen (Building developer), Trondheim Energi/Statkraft Varme (Energy Company). In addition Svartlamoen Housing Foundation was initially involved, and their reasons for withdrawing from the project will also be presented.

The 13 pilot projects included in this study are:
Trondheim Municipality

- Nardo School – ground water heat pump
- Rosenborg School and Sports Hall
- Ranheim School – sea water heat pump
- Ranheimsveien 149 – passive house and solar collectors

TOBB

- Ustmyra Housing Collective – intelligent metering and district heating
- Torvsletta Housing Collective – Rehabilitation
- Tonstad Housing Collective – Rehabilitation

Heimdalgruppen

- Miljøbyen Granås – Passive houses

Trondheim energy/Statkraft varme

- St. Olav's Hospital – River Water Absorption Chiller
- District Heating – Seasonal Waste Storage (de-baling machine)
- Ladehammeren Sewage Plant – Biogas boiler
- Kolstadflaten Housing Collective – Intelligent metering

Svartlamoen Housing Foundation

The 13 pilot projects involve a number of different forms of technology which require varying degrees of user intervention and the number of people involved in each project therefore varies. The pilot projects also vary in their success in relation to energy savings and effective operation of the systems. Success stories or particular challenges triggered more information about the projects. The reports from each pilot project therefore vary in scope and extent.

2.3 Method

The analysis of the end-users response associated with the 13 pilot projects presents what we have learned during the project period and highlights the advantages and barriers associated with technology installed in the individual projects. Understanding the actual impact of the technical installations relies not just on quantitative analysis of the technical data produced, but also depends on qualitative feedback from the people directly involved in the everyday use and operation of the technology installed, and provides answers about whether the initial aims associated with user interaction and energy savings were achieved. A qualitative survey of the 13 pilot projects has been made which allows the researcher to come in close contact with the everyday experience of the informants. This is achieved through the systematic use of ethnographic methods. Qualitative research is intended to be illustrative, and provide robust and detailed insight into the behaviour, use and experience of participants involved in the survey, but it does not necessarily give quantifiable conclusions. The conclusions are based on real-life examples which may challenge or support initial hypotheses, and which can importantly be learned from.

Two main methodological approaches have been used; a literature study including the reports from each of the 4 participating organisations, background information about the ECO-City project and on the separate projects (including protocols from meetings), and semi-structured qualitative interviews, with one or more representatives from each of the participating organisations. Interviews provided the majority of the information presented in this report. The interviews provide an account of the experiences of the participants in the 13 projects. The presentation of the interviews may be read because of what they can tell us about the phenomena to which they refer, in addition they will be analysed in terms of the perspectives which they imply (Hammersley and Atkinson 2007). The accounts although subjective provide participant knowledge about the technological and social situation which developed within the ECO-City project. What people say may be understood as evidence about their perspectives, and it also potentially provides understanding of the subcultures or cultures to which they belong. The ECO-City end-user group have been, or still are actively involved in the technical development, installation and operation of the energy effective technology installed in the projects. They can therefore be expected to have a particular understanding of the needs of the buildings in which it is installed and of the technology. In addition they may be understood to part of the technological culture associated with the organisations of which they are a part, and of the wider community in Trondheim. Their accounts are therefore shaped by the social, physical and technical context in which they occur.

Two basic interview guides were used, but the interviews varied in length in accordance with the scope of the project, and the role and commitment of the informant. In addition the interview series may be considered a cumulative hermeneutic process, whereby each interview was part of a series of interviews (Follo, 2008). The individual interviews were based upon previous interviews, and each stage of the interview process was analysed in relation to the previous set of interviews through a dialogue between the two researchers involved in gathering and analysing the information.

2.4 A Readers Guide

The report is divided into two main parts. The first part, which is the main part of the report, presents individual accounts of the 13 pilot projects. The 13 projects are grouped according to which of the 4 organisations they were associated with. A short account of the technology installed, a presentation of the end-users experience with the operation of the technology, and the advantages and barriers associated with it, has been written about each of the 13 projects. The second part of the report is the discussion and conclusion where the main research question "what have we learned" is discussed in light of the experiences with operating the technology presented in the first half of the report.

3 Trondheim Municipality

In 2001 Trondheim Municipality presented its first Climate and Energy Action Plan. The action plan marks the starting point for a general increase in engagement and activity in climate and energy related issues and measures within the municipality. The ECO-City application was written in 2003, the municipality chose to participate because it was believed both on both administrative and political levels, that the project would provide a boost to the municipality's activities related to the Climate and Energy Action Plan. The timing was right for the ECO-City project. ECO-City provided financial support for the implementation of actions but this, it was suggested by the project manager, was not a primary motivation for Trondheim Municipality. The municipality was aware that that they would have to contribute considerable amounts of time and funding if the projects involved were to be successful. Participation was therefore intended to be a learning process rather than being about financial gain.

Nidelven, Trondheim 2009, Photo Ruth Woods

3.1 Nardo School (Ground Water Heat Pump)

Nardo School is located approximately 2 kilometres south of the centre of Trondheim, in an area which contains both industry and housing. New Nardo School opened in October 2008. Designed by Eggen architects, it was built on the site of the previous Nardo primary school and kindergarten. The school buildings cover $7000m^2$, and the end-user group includes 385 pupils and municipal employees. The school is a low-energy building.

Nardo School, Photo Eggen arkitekter

3.1.1 What has been done and why?

Nardo School's energy use lay well within the official building standards set by TEK07 when it opened in 2008. The school is insulated against heat loss, and has windows which fulfil requirements for passive house standard. The school is connected to the district heating system, which is demanded by the municipality. A ground water heat pump which reaches a depth of 200–250 meters connects the technical room with 14 wells, and supplies the building with energy. The ground water heat pump is used to heat water for everyday use, and provides heating and cooling. On the warmest days of the year the technical operators try to avoid using air-conditioning and the heat pump is used to cool the building. The ground water heat pump provides an effective way of cooling the building during the evenings. The district heating system provides heat during the coldest days of the year.

3.1.2 Training and Operation

Trondheim municipality's operating engineers monitor the use of the system via a operational centre, and gather information about energy use and production. This group works with all the schools and kindergartens in the municipality. There is also an operator/caretaker who has the main responsibility for the day to day follow-up of the building.

The technical system today works well, but there were some initial technical problems. There was in the beginning too little pressure in some of the pipes connected to the groundwater pump, this problem was solved relatively quickly. A filter was installed in the circulation system after it was realised that the acidic water was causing the pipelines to clog. The acidity levels also caused leakages in the joints between pipes because the connecting pipes expanded. This stopped happening after the filter was installed. The filter has to be changed regularly and the PH-levels are also tested regularly. The problems with acidity developed over a period of time. It took therefore 3 years before the filter was installed. There is a danger that the pipes may corrode but the problem with acidity seems now to be under control.

The school's caretaker began in the job 2 years ago. The previous operator showed him how to run the schools technical systems; they worked together over a period of approximately a month. According to the operator the training period went well (Ref. Tømmervik). This was partly due to the fact that he had previous experience with working with ventilation systems. He has also a good relationship with the municipalities operational centre, they help each other. RESTEK installed the ground water pump. They service the machinery once a year and are helpful if help is required. The caretaker changes the filter on the ground water heat pump, this requires person who understands the system. The municipality depends therefore on help from several levels to run the school's technical system.

Nardo School's caretaker claimed that Nardo School was an easy school to run, both inside and outside. The school is part of the "Trebyen Trondheim" (Wooden City Trondheim) project, and the external cladding is all made of wood[1]. The caretaker suggested that the cladding limits the amount of maintenance the school requires. There is also a large well-designed technical room, the caretaker does not have bend down too much and provides a good overview of the technical installations. He was pleased with the energy results that the school has achieved and with working at the school. The caretaker said during the interview that, questions relating to energy use and the environment become more interesting when you are working with an impressive new establishment. However, he also suggested that people working with schools are in general aware of their own and the school's energy use (Ref. Tømmervik).

3.1.3 Advantages and Barriers

Nardo School is intended to be a good arena for learning and working in and this has, the informants suggest, been achieved. Comfort is an important aspect in the project. The school regards good air-quality as important, and energy use is concentrated on the ventilation system. There are some rooms that can become too warm, but the temperature is generally comfortable. One of the conference rooms has problems with air quality; the ventilation provided is not sufficient for the size of the room. It is possible to reduce the amount of energy used every year but that would result on lower air quality (Ref. Tømmervik). The main environmental impact that the technology has had is that the school has reduced the amount of energy it uses and the amount of energy that it buys in relation to energy levels in the previous school. The expectations about energy savings have been delivered in this project. It is a successful project (Ref. Lipphardt).

The school as a part of the Wooden City Trondheim project also has an environmental focus, looking at the sustainable impact of the use of wood as a primary building material. The combination of research focus between ECO-City and Wooden City Trondheim gave the Nardo School project a boost which has continued to have positive implications for school building development and the city's climate and energy policy and measures. The project has been useful in highlighting the cost-effectiveness of the technical systems installed, by focusing on the energy that has been saved (Ref. Lipphardt). The ground water heat pump was expensive to install, but it is suggested that it will pay off and be worth the investment in the long run (Ref. Tømmervik).

Nardo School was already in the design and development phase before it became involved in ECO-City. The grant from ECO-City was helpful, but the plans were already laid and it is suggested that there is a good chance that they would have been implemented without participation in ECO-City.

[1] http://www.trondheim.kommune.no/trebyen

3.1.4 What have We Learned?

Nardo School, photo Trondheim Property Management (Trondheim eiendom)

Nardo School uses very little electricity. It has the lowest electricity use of all the schools in the municipality (Ref. Tømmervik). The school is an important municipal pilot project. When it was built the school building cost more than similar building projects, but the gains have out-weighed the costs (Ref. Lundli). The municipality has been able to test solutions which have been used in other municipal buildings. The school is air-tight, and requires a good ventilation and cooling system. More traditional solutions which only include heat pumps would not have been enough. Initially it was a challenge to gain financial approval for the project (Ref. Lipphardt). The grant from the EU helped to get the project started. Nardo School was for a number of years the most energy efficient school in Norway, and it has been useful in helping to market Trondheim's climate and energy policy outside the city. It also helped the project managers argue successfully for the inclusion of similar measures in the schools and municipal buildings that were built afterwards.

The technology installed at Nardo School was relatively new and the project manager suggests that both technical advisors and building developers require knowledge about the systems being installed if they are to assure the quality of the technology and its operation. The industrial advisors and the building developers were sceptical, and it was therefore important that the project manager was knowledgeable and able to convince them of the importance of installing this kind of technology (Ref. Lipphardt). The caretaker suggests that it is important that those who will be operating the technical systems participate during the whole development process; this allows effective sharing of information (Ref. Tømmervik).

The ground water heat pump supplies most of their energy needs; they do not often need the district heating system.

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3.2 Rosenborg School and Sports Hall

The new Rosenborg School and sports hall opened in 2009. It is built on the site of the old school which was demolished in 2008. The school and sports buildings were designed by HUS architects. It is a middle school with 440 pupils and a staff of approximately 50 people. There is only 30 to 40 meters between the sports hall and the school, and they both have the same technical installations. The school building is 7560 m^2; of this 6900 m^2 is heated. The sports hall is 2849 m^2 and 2724 m^2 is heated.

Rosenborg School, Photo Ole Harald Dale

3.2.1 *What has been done and why?*

The aim was to reduce the school's total energy use, and demand controlled lighting and ventilation systems have been installed. The school is heated using a combination of radiators and under-floor heating, the ventilation system is used for air replacement. The space between the ceiling and the roof is used as a ventilation channel. The under-floor heating level is regulated by an outdoor compensated curve, which is only used to achieve comfortable ground-floor heat. Radiators which are regulated both by the temperature and the clock are used to heat the rooms. The system is timed to work between 7 am in the morning and 3 pm in the afternoon. However, achieving the best possible user-comfort also influences its operation. It is suggested that the technology allows effective operation, follow-up and the locating of technical problems (Ref. Nygård). The municipality has positive experience with the use of the similar systems in other schools. The amount of CO_2 and the indoor temperature are measured. It is a system which is often used in large classrooms and open landscapes where the everyday use can vary.

3.2.2 *Training and operation*

The operational personnel did not receive training prior to installation; this was because it was technology which the operators and caretakers from the municipality already had knowledge about. The school's caretaker looks after the everyday running of the technical installations, and this is followed up by the municipality's operational centre.

3.2.3 Advantages and Barriers

The main challenge that has been faced in association with the technical installations is poor air quality in the teaching areas. The calculated ventilation areal has during operation proved to be too small. A diversity factor for the number of people expected, and the type of room use was used to calculate the required dimension of the ventilation system. This was done to reduce the size of the ventilation units, which in turn reduced the amount of air supplied to the school and which now means the school has only has available 75% of the required amount of air. The operators have problems getting enough air into the building, and with air replacement. The generator working the ventilation system is too small. Certain teaching areas struggle with the problem more than others. There is a project group working on solving the problem with the generator, but a solution has so far not been found.

The municipality's operational centre measures energy use at the school every week. The school's caretaker also measures and follows-up energy use and is good at running the system according to the school's everyday needs. It is suggested in Adresseavisa, the local paper in Trondheim, that Trondheim Municipality is one of the best municipalities in Norway at energy saving, and bases much of its success on the operational centre and on the enthusiasm of its caretaking staff (Adresseavisen 30.10.2012). However this can not make up for mistakes made during the planning of the project and a number of the school's end-users have complained about headaches.

3.2.4 What have We Learned?

The project manager from the municipality described the building project as traditional in relation to the energy supply and use, and suggests that they would probably have achieved this level of energy efficiency without the involvement of ECO-City (Ref. Lundli). However, he also pointed out that if the energy use levels from the new school are good when compared with the energy use levels from the old school, they appear low because the new school only uses a third of the energy that its predecessor used. Old Rosenborg School had the highest energy use levels of all the school buildings within the municipality.

Trondheim Property (Trondheim eiendom) has some influence during the design and engineering process when planning new buildings or technical systems. This is done by actively following up new projects, as well as the service of these projects. The municipality also has specific requirements for the use and installation of buildings and technical systems. These requirements are regularly up-dated. In addition Trondheim Municipality has experience with similar demand controlled technology, but this did not prevent the project group from installing a ventilation system with too small a capacity for the requirements of the new school building. This has resulted in poor air-quality in the school building and reduced user-comfort. The technician interviewed suggests that it is important with close follow-up what is planned to be installed (Ref. Nygård). It is not enough that the technology is known, because each building is different and has different requirements according to end-user group and use.

3.3 Ranheim School and Sports Hall (Sea Water intake and Heat Pumps)

Ranheim is a suburb of Trondheim, 7 km east of the city centre, on the edge of the Trondheimsfjord. The school is a primary school with approximately 500 pupils and 26 staff. New Ranheim School opened in 2010 on the site of the old school. The school is 6703 m^2 in total, 6426 m^2 of this is heated on a daily basis. The sports hall is 5770 m^2, of which 5514 m_2 is heated. The heating and ventilation system runs during the school's opening hours. The school and sports hall are used for leisure activities during out of school hours, and the heating and ventilation system is also run according to these needs.

Ranheim School, Photo Trondheim Municipality

3.3.1 What has been done and why?

A sea water intake has been installed which is connected to heat pumps in both the school and the sports hall. Sea water is used to cool the ventilated air during the summer season. The aim was to save energy by using sea water as an energy source. Heat pumps are used for preheating tap water and heating the ventilated air, radiators and under-floor heating. The dimension of the heating system is 80/60; this means that the heat pumps provide basic heat and the district heating system supplies extra heat during the coldest periods.

The Ranheim School building is a low-energy building. The school's overall energy use is measure by a metering system called ENTRO from the Trondheim Energi electricity company. The municipality has also installed meters on the heat pumps.

3.3.2 Training and operation

The companies who installed the system introduced and explained its operation. There are 2 operators who look after the school and sports hall. A diver does an under-water check on the sea water intake once a year.

The system is energy efficient when it is working, but there are technical problems with the sea-water intake. The problem arose straight away. The quality of the water coming into the pump is not good. A lot of sludge and other particles come in with the water, and the sea water pump has now stopped working. They are struggling to find the right dimension for the pipes. When the sea water intake stopped working they had to stop using the heat pumps. At the time of the interview (11.09.2012) the system had been out of action for 4 months. The municipality's operating engineers have used a lot of time and energy trying to get the system to run effectively. A third party has been hired to examine what goes through the pipe system and what has gone wrong. The aim is to try and find other solutions, as well as potential solutions to the sea water intake problem.

3.3.3 Advantages and Barriers

The technician that interviewed was in general pleased with the Ranheim School building, and suggests that the school looks good and it has good technical solutions for heating and ventilation. The balanced ventilation system works well and the air-quality in the school is good. The building can be too warm in the summer, although sun-shading is installed (Ref. Nygård). However it is not just the sun which makes the building warm; there are several factors which influence the temperature such as air-levels and the internal load (people, pc's and smartboards). The sea water intake is not operational. Ranheim School and sports hall have therefore lost what they would have saved in energy use in energy use in relation to this technology.

The sea water intake and heat pumps have not achieved the energy savings that were expected because the operation is so unstable.

Ranheim School, Photo Trondheim Municipality

3.3.4 What have We Learned?

The use of sea-water as an energy source and for cooling is not a new idea, it has already been used for a number of years in the shipping industry and in Trondheim there exist successful examples, such as the heat pump system installed at the Royal Garden Hotel. The problems which are associated with the sea-water intake at Ranheim School are primarily associated with the sea conditions where the sea-water intake is located and the sea-water pump that was chosen. The technician from Trondheim municipality interviewed suggest that a more comprehensive assessment of the sea-bed conditions, sea-water intake and sea-water pump technology would have provided better solutions for the school or potentially enabled them to improve the existing system more quickly. The knowledge gathered before installation is important to secure the quality of the system installed (Ref. Nygård).

The school is a low-energy building. However, according to the project manager for the ECO-City project for the municipality, in contrast to Nardo School which is also a low energy building it does not stand out as a particularly interesting case in relation to energy efficiency and design (Ref. Lundli). Nardo School has the lowest energy use of all the schools in Trondheim and it has achieved national interest. Ranheim School has not achieved the same energy levels or interest.

3.4 Ranheimsveien 149 (Passive House and Solar Collector)

Ranheimsveien 149 is a housing collective for individuals in need of 24-hour nursing and care. The housing collective is located in a residential area close to Ranheim School and sports hall, and the Trondheimsfjord. The building was designed by Vis-à-vis architects and was opened in 2010. The housing collective is 752 m^2 includes communal areas and 7 apartments. There are 7 residents living there and approximately 7 members of staff.

3.4.1 What has been done and why?

Trondheim Municipality at the start of this project aimed to gather knowledge and experience about the building, operation and use of passive houses. Ranheimsveien 149 was, because of this interest, Norway's first officially approved passive house. The building, like Nardo School, is part of the Trondheim Wooden City project, and there is therefore extensive use of wood in the building. The aim is to reduce the amount of CO_2 from material production by using more wood in the construction process. In addition solar collectors have been installed, which are intended to heat the buildings water supply and to supplement the heating supplied by the district heating system. The building has LED lighting.

The project also has a strong focus on Universal Design, in addition to the environmental aspects associated with ECO-City. This is because of the needs of the end-user group who are living and working in the building. The intention is that it should be possible to adapt the apartments to the changing care/nursing needs of the residents. For example the inside of the building and outdoor environment are adapted to the needs of wheelchair users.

3.4.2 Training and operation

The building is compact and the technical installations are not complicated. It was suggested during an interview that the operation and control of the energy requirements of Ranheimveien 149 is much the same as it would be for a normal residential house. There are 6 technicians/engineers working in the municipal operational/control centre who are responsible for 200 municipal buildings. This group already has a lot of knowledge about the running of similar systems and did not need training after the technology was installed (Ref. Lindtorp). The residents and staff in the building do not need to know much about how the heating system works or the energy saving technology beyond being able to adjust the thermostat connected to the heating system. Those living and working there should only experience that they are living and working in a comfortable building that has passive house standard (Ref. Lindtorp). Within the wider ECO-City project learning and dissemination about energy use and efficiency amongst end-users was one of the initial focuses of the project. The comments by the project manager may be understood from the perspective that one of the end-user groups requires extensive nursing care. However the caring staff at Ranheimsveien 149 are also an end-user group, who is also directly influenced by the everyday working of the technical system. Greater understanding amongst this group has relevance. In ZEB report 1 it is suggested that it is important for the end-users to understand the heating systems affecting them, because understanding the system encourages them to use it more efficiently (Thomsen, 2011).

3.4.3 Advantages and Barriers

There have been no technical problems with the solar collectors; according to the project management they just do not produce very much energy. However, it is suggested by the project management that, there is no reason to remove them now that they have been installed. They can simply carry on producing what they are capable of producing (Ref. Lindtorp).

Ranheimsveien 149, photo Próndeimr

The building because it is a passive house requires little energy for heating; however the actual energy use is higher than was initially predicted. The expected savings related to energy produced by the solar collectors was overestimated. In addition the energy use by residents varies. The energy consultant is disappointed over the energy production associated with the solar collectors; he would have preferred to have achieved better results and to be able to recommend this kind of technology (Ref. Lindtorp). The use of solar collectors in

Ranheimsveien 149 has been a learning process. The knowledge gathered has been used in relation to planned projects in Trondheim (New Åsveien School will now not have solar collectors installed). It is also disseminated within the Norwegian big city network (Storby nettverk). However Ranheim veien 149 is not the only building within the region to use solar collectors, and a recent SINTEF report has shown the climatic challenges to be no worse than in for example Oslo and Hamburg. There is therefore reason to suggest that it is the technology and installation in this project which is the problem and not a general problem associated with solar collectors in Trondheim.

The building is described by the energy consultant as being "successful aesthetically". The aesthetic success he describes is based on his understanding that the choice of colours and materials is good, and that the rooms are intimate and comfortable. The consultant also states that the indoor climate is pleasant, both the temperature and air-quality are good. The residents and staff are comfortable, they like living there (Ref. Lindtorp). The passive house project has had several positive effects. The municipality has gained new knowledge. It was useful being the first passive house project because other actors have been interested in learning from municipality's experience. A lot of people now know about the project for example it was presented during the "Passivhus Norden 2012" conference. This has resulted in the municipality being particularly proud of this project.

3.4.4 What have We Learned?

The solar collectors were expensive and the energy savings related to them have been disappointing. It is suggested by the energy consultant from Trondheim Municipality that this has a lot to do with the local climate, because there are not a large number of sunny days in Trondheim. The technology is expensive and although the need for follow up and control of the technology is limited, it does require operational personnel to follow it up. These aspects, it is suggested, have equalled an environmental burden rather than an energy saving (Ref. Lindtorp). The solar collectors produce 5-6000 kwh/year based on approximately 20 days of sun. This is little and it will take a long time to pay back the price of investing in the technology. The project received money from ECO-City to install solar collectors. The energy results from the solar collectors at Ranheimsveien 149 are well-known amongst the municipality's technicians and engineers. Despite their general interest in the use of new technology, they now consider the use of solar collectors as slightly ridiculous investment within the climatic context of Trondheim. This response will be further discussed in the concluding section.

The "wooden city Trondheim" part of the project has worked well. They have used large amounts of massive wood in the building construction. The market demand for massive wood is not great and it is an expensive solution when constructing a building, but working with this kind of building provided the municipality with good experience (Ref. Lindtorp). The building was also successful as a passive house project; the building requires very little energy for heating.

3.5 Advantages and Barriers for the Trondheim Municipality

The project manager from Trondheim Municipality Hans-Einar Lundli is pleased with the participation in the ECO-City project and with the results of the pilot projects. The start of the project was somewhat demanding, but the project was a useful learning process and he would be happy to participate in similar projects (Ref. Lundli). The size of the project worked well, it was possible to meet and interact with the other consortium members and thereby come in contact with other European actors who are interested in energy related issues. However Lundli suggests that there should have been more contact between the different cities from the beginning.

The ECO-City project has resulted in more energy meters being installed in municipal buildings in Trondheim. It is suggested by Lundli that EU countries are in generally more interested in metering than has previously been the case in Norway and there are good examples from other countries. There was little focus on metering in Trondheim when the ECO-city project started, but this has changed (Ref. Lundli). However not all of the activities on this front are a result of support from ECO-City.

Work with the aims of the ECO-City showed that the initial funding application had a too compact geographical delineation of the community form in Trondheim. It was in general a complicated process getting the projects that they wanted to involve to be accepted into the ECO-City project. For instance, a bioenergy plant at Leinstrand School was not included because it was considered too far outside the area initially specified by the project application to the EU. The bioenergy plant was finally opened this spring, but the project manager suggests that it could have been realised earlier if it had been part of ECO-City (Ref. Lundli). The initial project proposal aimed to include a bioenergy building, but this was not achieved within the ECO-City project. The Ladehammeren Sewage plant has a biogas boiler but this was a different kind of project.

It is suggested by Lundli that there could have been more focus on dissemination in the ECO-City project, and that both ECO-City and Trondheim Municipality could have focused more on presenting the energy aims and results of the project outside the consortium. The population of the city of Trondheim in general knows little about the 12 pilot projects that have been completed and the energy efficiency measures which have been put into practice.
Also, the training and dissemination part of the ECO-City project was not fully realised. The Municipality has set in motion measures which are intended to increase user awareness, such as the Strømspare pris (Energy Savers Prize) for schools and Miljøfyrtårn sertifisering (Environmental Lighthouse Certification). These measures have received some support from ECO-City but the initial project application suggested that a much larger part of ECO-City would centre on dissemination and user awareness.

4 TOBB

TOBB manages and administrates 100 affiliated housing cooperatives, which includes more than 12,300 homes in Trondheim and the surrounding area. TOBB aims to be a forerunner in the field of energy efficiency in buildings. Participating in the Eco-City project fitted well into their company profile. Runar Skippervik, the section leader at TOBB has been working with the Eco-City project since 2006. He was already interested in energy use and the environment when he started working with the project, but participating in the project has deepened his interest further.

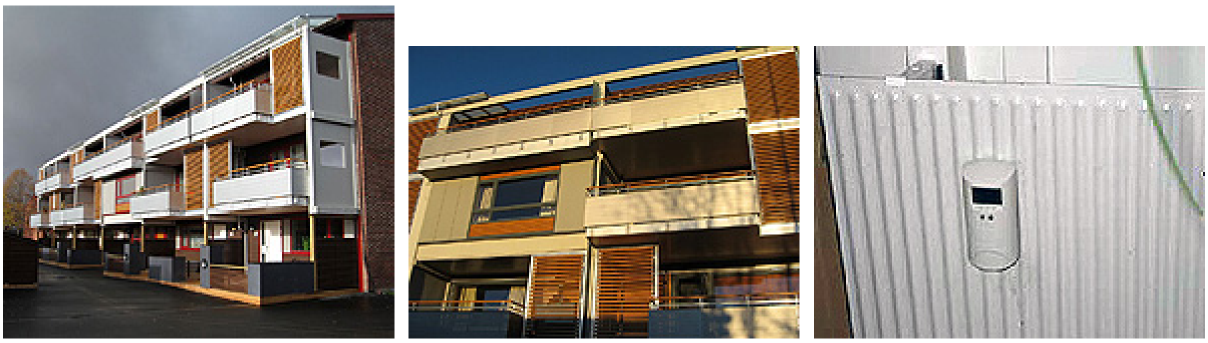
4.1 Ustmyra Housing Cooperative – District Heating and Intelligent Metering

Ustmyra is a housing cooperative, built in 1976, consisting of row-houses and apartment buildings (4 floors). There are a total of 192 apartments within the housing cooperative. The housing cooperative is located in Kattem, a suburb on the southern side of the city of Trondheim.

Ustmyra Housing Cooperative, Photo TOBB

4.1.1 What has been done and why?

The visions and intentions for the project were formulated by: COWI (energy guidance), TOBB, and the housing cooperation's board of residents. The motivation for the project was to save energy, but the project was started because there was a general need for building upgrading (renovation of facades, general face-lift within the cooperative) which also actualised ambitions in relation to saving energy (Löfström, 2012). The target was set at saving 40% (30% technical solutions, 10% resident awareness and diminished energy use). The outdoor facades and ceilings which are in contact with the loft have been re-insulated (15cm). In addition the apartment buildings have replaced windows and introduced individual measurement of supplies from the district heating system. Residents instead of receiving a common bill and individual payment based on areal use, now are billed based on actual consumption.



Ustmyra housing Cooperative, photo Trondheim Municipality

4.1.2 Training and Operation

In addition to project management by Runar Skippervik the project has primarily involved two individuals from TOBB. The entrepreneurs who delivered the metering system (Istad) were also involved in the initial operation. The housing cooperative started using the metering system in 2007, but there was a trial period and individual billing was introduced in 2009.

TOBB has been provided with basic information about the metering equipment installed, but Istad Norge AS, who installed the meters, take care of operations. A technician from Istad does the readings through a wireless connection. The information is then analysed and 1 person from TOBB sends out the bills based on these readings. A caretaker also supervises the operation of the system when necessary.

4.1.3 Advantages and Barriers

When the agreement was made with the housing cooperative, there was in praxis only one supplier that could deliver the necessary equipment, Istad Norge AS who delivered the equipment and Harald VVS who installed the meters. The installation work was not carried out without difficulties. One reason for this was that the buildings were not "suitable" for individual metering due to the fact that the plumbing was originally installed with the intention of getting heat to where it was needed using the shortest amount of time and the least amount of work (Ref. Skippervik). This made it difficult to find the correct location to install the meters and measure usage. In addition, the plumbing system was initially visible in the apartments, but many residents have made renovations and covered the pipes over, and this made it difficult to mount the meters on the pipes. Installing and gain acceptance for the metering system has, according to Skippervik, been challenging.

Some of the meters have not functioned properly, and this challenged the residents trust in the system. For instance, some meters were mounted on the pipelines for cold water instead of hot water. This is described by Skippervik as, "engineering difficulties". Malfunctioning meters and other technical problems has raised questions about whether the bills that residents receive are based on correct information. In addition, there has been no means for the residents to control their own energy use, i.e. there is no display with information for individual households. The supplier controls the measured data.

4.1.4 What have We Learned?

The specifications from TOBB on what was to be installed should have been more detailed. TOBB now believes that they should have made more explicit demands on the company providing the meters, and made sure that these specifications were included in the contract. They also now regret that a service agreement and a guarantee period were not part of the initial deal. The equipment supplier should have complete set of solutions to cover needs of the client (Ref. Skippervik).

In relation to Ustmyra's residents, it would have been preferable if they had been offered their own monitors. This would have lessened the scepticism towards the measured data. Scepticism would also have been reduced if all the meters had functioned from start, but this kind of challenge is difficult to avoid when testing a new solution. The project has received a lot of positive attention; it received an honourable mention the Trondheim Municipality 2009 Energy Prize. However the individual metering system is not yet economically rational and the cost has so far been discouraging. On the other hand, the project manager pointed out that TOBB has a responsibility to act as a pioneer; it should be willing to test out new solutions. TOBB has learned a lot during from the project, but it has also been challenging (Ref. Skippervik).

4.2 Torvsletta Housing Cooperative – Rehabilitation

Torsvetta housing cooperative has 246 apartments in row-houses and small apartment buildings. The first residents moved in the spring 1974. The architects were Petter Bakøy AS. The housing cooperative is located in the Kattem neighbourhood of Trondheim.

Torvsletta BRL, Photo TOBB

4.2.1 What has been done and why?

Initially, the board of residents formulated some visions, and the starting point was a general need for upgrading /renovation (Löfström, 2012). TOBB represented by Runar Skippervik became involved in the process, along with the architects (ROJO) and eventually the whole housing cooperative, including the residents, became involved. The board of residents initially wanted a face-lift to improve the building facades and to reduce the use of energy. TOBB also wanted to include balanced ventilation, and the requirements for this were investigated. However, it turned out to be difficult to find the physical space for a ventilation system in the building. An external VVS-consultant was involved in the process, but did not come up with any good solutions.

The measures which were put into effect were extra insulation, the restoration of the building facades and the installation of new windows. The aim was to achieve a 25 % reduction in electricity use. A 22% reduction has been achieved. Balanced ventilation was never installed.

4.2.2 Advantages and Barriers

This project was based on known technology, and there were no particular difficulties involved in the process of carrying out the measures.

4.2.3 What have We Learned?

The project has been inspiring for other housing cooperatives (Ref. Skipervik). There are no plans to change the solutions chosen in the near future. The building ventilation could have been improved, at the present time it is only possible to regulate it manually by using the window vents. The rehabilitation has resulted in a 22% reduction in energy used, compared to the set target of a 25% reduction, which TOBB suggests is an ok result considering the conditions in which this has been achieved. The installation of balanced ventilation is a possibility for the future. Apart from not finding a ventilation system the project was not very challenging and the results are as can be expected (Ref. Skippervik).

4.3 Tonstad Housing Cooperative – Rehabilitation

Tonstad BRL, photo TOBB

Tonstad Housing Cooperative includes 144 row-houses and four-family homes. The first residents moved in June 1979. The architects were Visavis arkitektkontor/staden bygg. The housing cooperative is part of the Tiller neighbourhood which lies on the southern side of Trondheim.

4.3.1 What has been done and why?

Initially, the housing cooperative aimed to reduce their use of electricity due to high cost of purchasing electricity. However, TOBB argued for increased user-comfort by increasing the building's insulation thickness and also suggested balanced ventilation to improve indoor air quality. A 30% electricity saving was set as a target. As in the other two housing cooperatives involved in the ECO-City project there was a general need for upgrading the buildings.

4.3.2 Advantages and Barriers

Adjustments were made to the ventilation system, making it possible to install the equipment in different types and sizes of apartments. The effect has been to reduce the system capacity in relation to the size of the apartments (40-50m^2). The reduction has not been without its problems. The system is standardised and suitable for apartments of 70-200m2 and at the time of installation there was no equipment available that was suitable for smaller apartments on the market. The market is now changing and it may be assumed that a new project will not have the same problems. In addition some of the residents protested after the equipment was installed because they were not prepared for the visual impact of the equipment in their apartments.

4.3.3 What have We Learned?

The project has been an inspiration for other TOBB projects that wish to install balanced ventilation in in-row houses (Ref. Skippervik). After the first adjustments were made the ventilation system has worked as planned. The target saving set by the project was a 30% reduction in energy use, and this has been more or less reached. However, the apartments are equipped with wood burning stoves, making evaluation of the end results more difficult. The project manager has adjusted the results after doing a short investigation amongst residents about the household use of wood burning stoves. The final presentation of the plans to install the system for each apartment could have been better communicated, so that the residents would have been better prepared for the end result and changes in their apartment. Residents could have been shown pictures of what the ventilation system would look like (Ref. Skippervik). According to Skippervik, there is always room for improvements during the planning and development of a new project, but the rehabilitation of Tonstad housing Cooperative has been a success. There are currently no plans to change the equipment or its function.

5 Heimdal Bolig

Heimdal bolig AS (previously known as Heimdal gruppen) has been developing and building housing in Central Norway for the last 30 years. This is done in collaboration with their sister company, Heimdal eiendomsmegling (Real estate agency). Heimdal Bolig's main overall aims are to develop good areas to live in and to achieve customer satisfaction. It is suggested by the company manager that sustainable housing will be achieved if they utilise the site so that their customers both wish to live there and can afford to live there. The utilisation of the site should also be in accordance with municipal expectations (Ref. Munkhaugen 08.11.2012). Heimdal bolig aimed with the Miljøbyen Granåsen project to establish a strong environmental image.

5.1 Miljøbyen Granåsen (Passive Houses)

Miljøbyen Granåsen is a new housing project on the eastern side of Trondheim. 300 dwellings will be built on the site, and when it is completed the site will include 17 detached houses, 80 row-houses, and apartment buildings with 210 apartments. Heimdal Bolig AS aims to build environmentally friendly housing, and it is Norway and Scandinavia's largest passive house project. The first residents moved into the detached houses in April 2012 and into the first row-houses during the early summer. Row–houses are still being built and so far none of the apartment buildings have been completed.

Miljøbyen Granåsen, September 2012, Photo Ruth Woods

5.1.1 What has been done and why?

The total energy consumption in a passive house is approximately half what can be expected in a traditional Norwegian house, for example a house built in the 1980's. This is achieved through the recirculation of heat through the ventilation system, better windows, thicker insulation and fewer air leakages. Heimdal Bolig AS have also collaborated with ENOVA in achieving their energy aims for the houses and apartments. Enova is a state-owned enterprise, owned by the Norwegian Ministry of Petroleum and Energy. Over a period of ten years, the enterprise has worked to trigger energy efficiency measures and renewable energy production.

The detached houses and row houses have a concrete shell with an outer wooden cladding. The apartment houses are a combination of concrete and steel, with wooden cladding. The energy aim is 86 kvh/m^2, this is considered an important aim in relation to future environmental requirements. The houses are built on a sunny building site, and they are positioned in order to catch as much sun as possible. They connected to the district heating system, are also well insulated, compact, but they are not equipped with smart-house technology. The aim is that they should be a popular/down to earth housing type. They are not directed towards a special kind of customer, one who is particularly interested in design and technology.

Other passive house projects in Norway and abroad have been used as inspiration, for example the company visited Løvåshagen outside Bergen (Wågø, 2012). This resulted in them choosing simpler technical solutions than those used in Løvåshagen. The company also did market research on the public's interest in passive housing.

Miljøbyen Granås, September 2011, Photo Ruth Woods

5.1.2 Training and Operation

SINTEF has worked with Heimdal Bolig As in an advisory capacity on the building of passive houses in Miljøbyen Granåsen, both on an educational level by organising courses for the construction and engineering personnel, and by following up the construction process for example by checking that the building meets passive house requirements by for example testing the air-tightness of the buildings. The intention through this collaboration is for Heimdal Bolig As to lead the field within the building of passive houses in Norway.

The starting point for the building project is traditional Norwegian building styles, knowledge and craftsmanship. These have been adapted for use in passive houses in collaboration with researchers from SINTEF. There has been a lot of focus on air-tightness. To avoid problems with dampness the building took place under tents. One of the entrepreneurs attempted to build a section of row-houses without a tent. This was particularly unsuccessful because rain caused the building materials to become damp, and some parts of this section had to be rebuilt from scratch.

5.1.3 Advantages and Barriers

Miljøbyen Granåsen is the best building project that project manager has participated in. The planned project has been realised in relation to current Norwegian building (TEK07, but the aims were up-graded so the houses also fulfil passive house requirements in NS3700). The project manager suggest that they have achieved even better results than expected, results that are actually better than the required building standards (Ref. Stensrud). The craftsmen/building workers have been motivated and have aimed high in terms of standards.

Project manager Stensrud suggests that there has been less focus on economics of the building project than is usual. There has instead been a focus on innovation, simple solutions and planning ahead. However the houses are 6-7% more expensive than was initially expected. This is not a large difference and more than 100 houses have already been sold.

When they started the project the Norwegian passive house standard was not defined. This was challenging for the project, but they used consultants from SINTEF to make sure that there would not be problems when the standards were defined, as they now are. In addition the basic building principles were the same as they would have been for a traditional Norwegian house, and this helped the building process (Ref. Stensrud).

The district heating system has been criticised by some residents at Miljøbyen Granås for not being environmentally friendly enough. They were also disappointed that the houses did not have solar collectors installed. Solar collectors had been suggested in the initial housing project design. They residents suggested that solar collectors would have been a more energy effective and environmentally friendly than the district heating system. 2 residents are sceptical to the district heating system because they have heard that the system leaks heat before it reaches the houses and because the district heating system burns oil and gas (Ref. Stensrud). The project manager for the development of the refrigeration unit from Statkraft varme pointed out that they have documented that the district heating system uses a high percentage of environmentally friendly waste, and it is only during the coldest periods during the year that they burn oil or gas (Ref. Hagen). Statkraft varme aims to increase the amount of biogas that they use, and thereby further reduce their need for oil and gas. The decrease in the use of oil and gas, and the increasing use of biogas is information which could be presented to a wider audience, and in this way help to decrease scepticism to the district heating system and increase the effect of the community design approach which is part of the ECO-City project.

5.1.4 What have We Learned?

Gaining necessary knowledge and competence with the field of passive housing takes time. Heimdal Bolig AS have spent 2 years training their construction workers in the building of passive housing. It is suggested by the project manager that it would perhaps have been useful to start the advisory and training process earlier (Ref. Stensrud). It also takes time for their customers to develop an interest in passive housing. It is important that the housing is affordable and “No one wants to live in a research project”, customers want to live somewhere they know will be safe (Ref. Munhaugen). Potential residents do not go around comparing passive houses that are on the market with low energy houses that are also on the market. They compare passive houses with houses from the 70's which is what they have often direct experience with (Ref. Munkhaugen 08.11.2012). Building standards (TEK10 and TEK15) are therefore ahead of the housing market.

Heimdal gruppen have learned some things by trial and error and the project has required creative solutions. The first houses were not air-tight enough and they had to go back to these houses and make them more air-tight. This was useful experience when they were building the next group of buildings. They discovered for example that the houses were leaking heat through the foundations. One of the entrepreneurs found the solution for this using insulating foam. As mentioned earlier in the text, one entrepreneur discovered that building under a tent is necessary within the context of the damp local climate (Ref. Stensrud).

Their customers have not shown an enormous interest in passive houses. The project manager suggests that potential customers simply do not know what a passive house is, or have gained a negative impression about them through the media. This is experienced as frustrating as the houses built at Miljøbyen Granåsen are in general of better quality than other new houses available on the market today. However the project manager also suggests that residents with an academic background or a particular interest in environmental technology have shown an interest in passive housing, and had before purchase some knowledge about what it means to own a passive house (Ref. Stensrud).

6 Trondheim Energi/Statkraft varme

Statkraft varme (State power heat) is part of the Statkraft Group and has been working with district heating since 1982. The company has 112 employees in Norway and Sweden, and is a leading national player in the development and operation of district heating. Participation in the project suited Statkraft varme's company profile as they are interested in sustainable energy systems and the testing of new solutions. The market for producing, delivering and selling energy has become increasingly competitive, and this means that it important for them to find new business models, and to create advantages within the market. A recent market analysis predicted that changes would occur on the market within the predictable future, which made participation in this project beneficial, i.e. it allows Statkraft varme to lead the development within certain areas on the market. It is positive for the company profile to be involved in and associated with projects which have a sustainable focus.

6.1 St. Olav's Hospital - River Water Absorption Chiller

St. Olav's Hospital is a university hospital and the South-Trøndelag regional hospital. The hospital is owned by the Central Norway Regional Health Authority, and is responsible for health care associated with a population of 275,000 individuals. The hospital has approximately 9600 employees. St. Olav's was officially opened in June 2010, but the entire hospital building project will be completed in 2015. The new hospital when it is completed will have a total area of 197,500 m^2. St. Olav's hospital requires a large and effective cooling system.

St. Olav's Hospital, Photo: Erland Knutsen/NRK

6.1.1 What has been done and why?

The main aim was to use the district heating system to provide cooling for St. Olav's hospital which requires cooling all year round. Statkraft varme`s district heating system produces more heat than it requires and this surplus heat will be used to cool the hospital. Ecology, safety and environment are keywords which were mentioned by the project manager as important in the cooling system project (Ref. Moen). Ecology and the environment are keywords for the ECO-City project in general, and may be applied to all the 12 completed projects. Safety is also an aspect which is also present in the 12 projects, but it does have particular relevance in the hospital which is providing health care for so many individuals, a reliable system is therefore important.

Much of the necessary technology required to support the river water absorption chiller (refrigeration system) was already in place in the new hospital. A cooling system had already been installed, there existed a system to collect river water, and the hospital is connected to the district heating system. A system was needed that could deliver cold air and that would provide a secure deliverance to the hospital and Statkraft varme has therefore installed a refrigerating plant (type: absorption refrigerator). Refrigeration is produced using heat from the district heating system. Central Norway Regional Health Authority is the owner of the system which became operational during the summer 2012.

6.1.2 Training and Operation

There are 2 operators dedicated to the refrigeration plant, but everyone in the control room at Statkraft varme has knowledge about the system and is involved in its operation. The operators have not asked for more information about the running of the unit. Statkraft varme have similar cooling units in other places in Trondheim and the system is for most of their employees, known technology. The hospital is very happy with the cooling system, but it is unlikely that they can tell the difference between the cooling that was delivered before and after the installation of the new cooling system (Ref. Hagen). The refrigeration plant has a life-span of 15-20 years and it will be audited after this period.

Statkraft varme are responsible for all the measurements, gathering of information and analysing the results (measuring volume and temperature). The continuous follow-up on the use gives continuity and enables optimal the operation of the plant, which Statkraft varme suggest encourages flexibility (Ref. Moen). During the future operation of the plant Statkraft varme aims to avoid the peak-loads by achieving steady continuous consumption. A compressor is used as a backup when peak-loads become unavoidable, and the aim is to minimize the need for it to be used.

6.1.3 Advantages and Barriers

Statkraft varme consider St. Olav's Hospital a satisfied customer and it was important within the project to achieve customer satisfaction (Ref. Moen). They are satisfied because the main task which is to deliver the cooling to the hospital has been achieved and the building is comfortable. The main advantages associated with the cooling unit are that it allows more effective use of the district heating network, and it enables the St. Olav's hospital to cut out its electric powered cooling. Cooling towers are not required and this allows noise reduction. The hospital requires a reliable system. A shutdown in the cooling system could have serious consequences for the patients. The choice of solution was therefore important. Statkraft varme used more money than expected to secure the delivery of a reliable system. The system that was chosen requires little maintenance because it has few moveable parts. They had to enlarge the building in which the cooling unit is installed because of its size. Otherwise there have so far been few operational challenges.

ECO-City played a role in encouraging the projects` development. The project group analysed end-user-needs and the cooling requirements of the building. The refrigeration system was direct a result of measurements that were made as part of Eco-City. A cooling unit would have perhaps been installed without the encouragement of ECO-City, but it would not have happened so quickly. Eco-City contributed to increasing the engagement in the optimal the running of the plant (Ref. Moen).

6.1.4 What have We Learned?

The St Olavs Hospital required a new refrigeration plant, and the needs of the site were studied in detail by the project managers before the technology was chosen. For instance, in 2006, measurements of the hospital cooling needs were carried out. Use scenarios were developed to help the project group to decide when it was the correct time to install, and to decide what technology to install. The project demonstrates the importance of having the right technology installed at the right time and is also an example of how important planning and timing is in a "high-risk" project, as safety and the comfort are particularly important in a hospital (Ref. Moen).

The delivery process is long, it is therefore important that the planning process should be thorough. Training of the personnel is important because the cooling unit maybe relatively unknown technology. It was demanding installing a new refrigeration plant alongside an existing one. Shutdowns are challenging for the hospital, and timing is therefore important to enable them to minimize the shutdown time. The cooling unit is still new; therefore the outcome of the project is at the present time uncertain. The project manager suggests that the results will be similar to what is produced by similar units (Ref. Hagen).

6.2 District Heating – Seasonal Waste Storage (De-baling and Cutting Machine)

Heimdal District Heating Plant, Photo Trondheim energi

The Heimdal District Heating Plant receives both industrial and household waste which is incinerated. This process produces heat which supplies the district heating system in Trondheim. Waste thereby becomes a valuable material. The waste is source-separated or segregated in a sorting facility. 60% of the waste comes from households in Central-Norway. The rest is from a private waste sorting facility that receives waste from industry in Trondheim and surrounding areas.

6.2.1 What has been done and why?

The aim of the project was to develop a cutting machine for bales of industrial waste which would remove straps and plastic, and chop the waste into manageable pieces. Previously the bales had to be manually unwrapped and had ended up in the waste incinerator in pieces which were too large to burn effectively. This caused combustion problems, and unburned waste in the ash in the base of the incinerator.

The need for district heating in the summer is much less than during the winter. To avoid sending waste heat up to the birds during the summer it has become necessary to store waste, and the industrial waste is therefore baled and packed in plastic (Ref. Hagen). This waste is then burned during the winter. Increasing the amount of waste being burnt during the winter reduces energy related expenses because waste replaces the oil and gas. Manual unpacking of the bales was necessary to avoid and a machine was needed that could unwrap the bails, and cut the waste up into small enough pieces to allow effective incineration.

An overview of the de-baling and cutting machine. The Walking floor which transports the bales is at the front of the picture. The de-baling and cutting machine is lowered when in use. In front of the machine is a footbridge with a protecting wall, photo Statkraft varme

In addition to the aims associated with ECO-City, there was a general need for upgrading of the district heating centre. By doing so Statkraft varme are able to offer flexibility to those who deliver industrial waste, because these companies now no longer have to store their own waste. It has now become attractive for companies to deliver their waste directly to the plant.

The main aim with the project has been to support the running of the whole plant more effectively by increasing the incineration capacity. The de-baling and cutting machine upgrades the whole incineration concept. More waste is put through the system which produces more heat for the district heating system. The system provides heat to both public and private buildings in Trondheim.

The intention was that the de-baling and cutting machine should be installed and in use in 2008. However the first prototype was not effective enough. This machine only cut off the plastic, and the waste was not cut up into small enough pieces. They had problems getting the waste through the grinding machine. The new machine was completed in 2011; this machine grinds the waste up into smaller pieces.

6.2.2 Training and Operation

The de-baling and cutting machine was developed by a team including of the supplier, Stavanger engineering, the project leader Espen Hanssen from the Heimdal District Heating Centre, and operators and maintenance personnel also from the district heating centre.

The head of the project received training and information about the running of the machine in connection with the commissioning of the machine in 2011. The relevant operational and maintenance personnel also received training at this point. There are currently 3 people employed in the waste reception area who are able to run the machine. One person is required to run the machine at a time. Statkraft varme is responsible for maintenance.

The employees at Statkraft varme have jobs with which are directly concerned with questions associated with the environment and reducing the amount of energy used. When asked whether they had become more concerned about these questions after being involved with the development of the de-baling and cutting machine, the head of the project said no, these were things they were dealing with every day. They were interested before the machine was installed and they continued to be so.

6.2.3 Advantages and Barriers

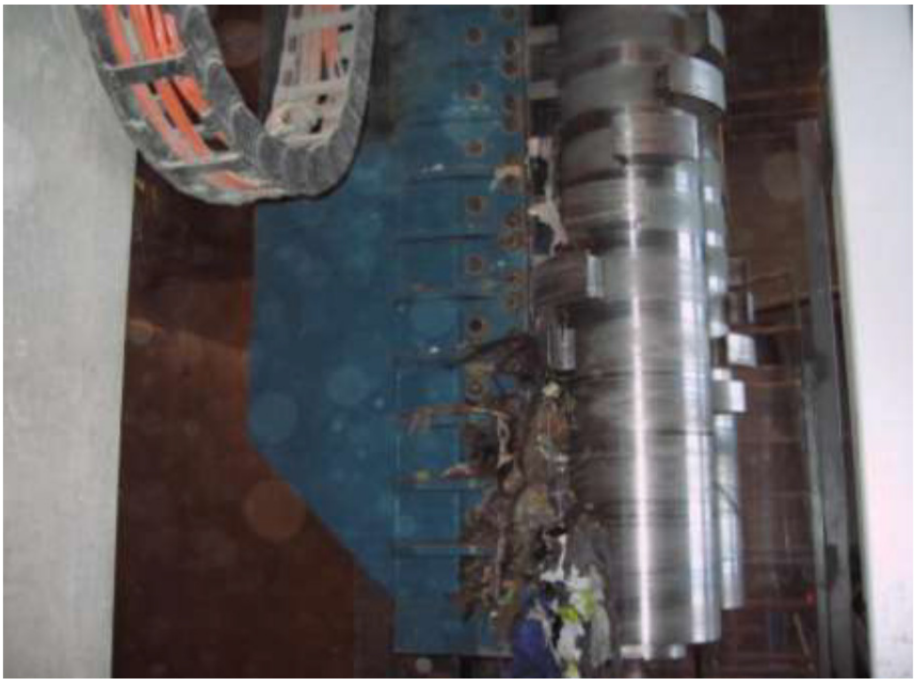
The greatest environmental benefit associated with the machine and the seasonal storage of waste, is that Statkraft varme is able to reduce the use of oil and gas to providing heat during the winter. They are still dependent on the use of oil and gas during the coldest periods, but this percentage has been reduced.

The de-baling and cutting machine has removed the need for the manual unwrapping of the bales and chopping of the enclosed waste. This has released extra capacity amongst the operators at the plant. The system also allows storage. In addition their clients are happy about being able to deliver waste and not having to store it themselves. The estimated need for storage was bigger than the actual need. Extra capacity gives Statkraft varme flexibility in relation to customer needs and their own growth potential. The project manager suggests that they need more waste to be delivered to their plant, and they aim to win more contracts for waste (Ref. Moen).

The total cost has been much higher than expected and the development of the technology has taken much more time due to delays. Eco-City support has been useful during the development of the de-baling and cutting machine. During the first stage in 2008 when the initial prototype did not work as planned the project would probably have stopped there without ECO-City's financial support (Ref. Hanssen). However it was an important investment, one which makes sure that waste can be burned.

6.2.4 What have We Learned?

There is little similar technology already developed. Statkraft varme have had to use their own experience and knowledge, as has the supplier, Stavanger Engineering. The representative from Statkraft varme suggests that the whole process of developing the de-baling and cutting machine has been interesting (Ref. Hanssen).



A close up of the shaft with the parts for cutting/grinding and scrapers (Illustration Statkraft Varme).

The de-baling and cutting machine was installed in 2011, so it is too early to say whether the predicted energy savings will be realised. The intention during planning was that the machine should deal with 40 tons of baled waste every 20 minutes. This has not been achieved; it takes ca. 1 hour and 20 minutes to deal with 30 tons of waste (a full loaded lorry and trailer). It is now suggested that the initial aim was unrealistic (Ref. Sluttrapport Statkraft varme 2011). Statkraft varme have no plans to introduce a machine that works faster, the technical speed that it works at today is acceptable (Ref. Hanssen).

The de-bailing and cutting machine is a specialized solution, which Statkraft varme have directly involved in developing. The developmental process was demanding and they would perhaps on the basis of hindsight not have chosen this alternative. They would instead have built a more integrated machine, a standard type of crusher. This kind of machinery could have been an alternative for other companies who require similar technology but who are unable to install an integrated crusher. It would have been possible for Statkraft varme to have built a standard machine on the outside, but security and the analysis of the waste delivered are also aspects which have to be considered. These aspects would not have been effectively under control if the machine has been outside. The waste is to be crushed has to be controlled before it is sent onto the rolling band.

6.3 Ladehammeren Sewage Plant – Biogas Boiler

The Ladehammeren Sewage plant is owned and run by Trondheim Municipality. It is a mechanical-chemical primary precipitation plant which purifies waste water produced by the eastern side of the city of Trondheim. The waste water comes from households and businesses, corresponding to a population equivalent of 120.000. The treated water is pumped out into the Trondheim fjord at a depth of 42 meters.

Ladehammeren Sewage Plant (illustration Trondheim Municipality)

During the treatment process slurry and sand are removed from the waste water. The slurry produces the biogas which is exploited by Statkraft Varme in the district heating system.

After being separated from the water that is to be treated the slurry is pumped from the sedimentation basins into evaporators. The water in the upper slurry evaporators then overflows and is removed so that the dry matter in the slurry is increased. The slurry is then pumped through a slurry screen to remove unwanted particles and fibers. The next step in the process is pasteurization where the slurry is heated in a shell and tube (heat) exchanger, consisting of 1,500 m pipes. Heated slurry is held in pasteurising tanks at a high temperature (65 °C), so that bacteria and viruses are killed. In step 2 of the pasteurisation process the slurry is cooled to about 40 °C before it is pumped to the digestion tanks where it is kept for 15 days without access to air (anaerobic digestion). Bacteria then break down the organic matter in the slurry, allowing the sludge to decrease by 1/3. The slurry is then stable and has fewer odours. The final part of this process produces the biogas which contains about 2/3 methane (CH_4).

6.3.1 What has been done and why?

Trondheim Municipality contacted Statkraft varme in 2007 because they wanted to make use of the waste heat produced by the methane gas from the sewage plant. The slurry produced by the sewage plant produces methane gas which was previously destroyed by being burned off as a flare over the sewage plant. The main environmental concept was that the municipality wanted to reduce the burning of fossil fuels and exploit the waste gas which the sewage plant produced. In addition the local population was reacting negatively to the burning of the methane gas. This gas was burnt sporadically, and the sudden flame that appeared in a part of Trondheim which is a popular recreational area, was by some members of the public considered frightening. The public also responded negatively the visible waste of the methane gas.

A biogas boiler and a biogas burner were installed in 2008. *More technical information*
The gas is fed to a boiler which produces hot water. Hot water is used for heating the ventilation system and the heating of the pasteurisation process in the treatment plant. The excess heat goes into the district heating system and supplies heat to dwellings, local businesses and municipal buildings.

Biogas boiler (Illustration Trondheim Municipality)

6.3.2 *Training and Operation*

The sewage plant is owned and operated by Trondheim Municipality. Statkraft varme operates the district heating system and is not involved with the day to operation of the biogas boiler. Service is done the suppliers. The energy production from the boiler is measured on a monthly basis.

The day-to-day running of the biogas boiler is done by Statkraft varme, and the client benefits from not to have to do things that are not within their main field of expertise. The operational personnel from Trondheim Municipality and from Statkraft Varme received information about the running of the biogas boiler after it was installed. The biogas boiler is operated by remote, and the 12 operators from Statkraft Varme run the boiler using a shift plan. The daily running of the biogas boiler is effective, and the project manager spoken to is happy with the operation of the boiler (Ref. Utne). However he also suggests that there is always room for improvement. On one occasion the boiler stopped working and the operators did not know enough about how the boiler worked, and were unable to start it again. The biogas boiler is one of the smallest plants on the district heating network, and knowledge about it and how it works has, it is suggested, perhaps not been the highest priority (Ref. Utne). However apart from this one occasion and problems with pump pressure after installation the biogas boiler works well.

As a part of daily operations, they try to avoid shutdowns, especially during the winter months. It is therefore necessary to plan maintenance, so that shutdowns take place during the summer months when there is less need for the heat being supplied by the district heating system.

6.3.3 Advantages and Barriers

The sewage plant offers a source of heat which reduces the district heating systems reliance on fossil fuels during the coldest period of the year. This heat was previously burnt off, which was a waste of energy and the local population considered it an environmental problem.

The gains: Statkraft varme have reduced their dependence on fossil fuels during the coldest period in winter.
Trondheim municipality is now exploiting an energy source which was previously wasted.
The excess biogas can now be sold to others.

ECO-City provided Statkraft varme the funds to implement the planned biogas boiler and the opportunity to promote the project to a wider audience. However Statkraft varme consider that it is likely that they would have installed the boiler anyway. The biogas boiler fits well within the wider context of the district heating network.

After the initial trial period of 3 months (the guarantee period) was over the biogas boiler has worked well. Statkraft varme have no plans at the moment to change changes to the biogas boiler, but it is suggested that if the sewage plant grows then it will be necessary to make changes to the boiler. The sewage plants growth depends on the city of Trondheim and the growth of the population. Population growth will mean increased amounts of waste water to be treated and the production of more biogas. A growing population will also require more from the district heating system.

The concept was described by the project manager as a win-win concept. Statkraft Varme wanted to increase their capacity, to avoid wastage and to use it up. The sewage plant had some extra biogas that was not used, and that can now be utilized (Ref. Moen). The Ladehammer purification plant does not have to run the biogas boiler, and can focus on their main activity which is the purification of water. Statkraft varme can avoid burning oil during peak periods because the purification plant is now self-supplied with heat and only tops up with oil when necessary. They are now connected to the district heating system which provides the top-load instead of oil. Statkraft varme has another happy customer.

6.3.4 What have We Learned?

The project manager recommends the production of energy from this kind of plant. The methane gas, he suggests, is a good source of energy and the necessary technology is already tried and tested, and therefore causes few operational problems (Ref. Utne).

Statkraft varme consider the biogas boiler to be a relatively small project, both in cost and effect. The project manager suggests that the interest in the technical system and knowledge about the biogas boiler has been proportional to the size of the project and the complexity of the technology used. This resulted in too little being known about the operation of the biogas boiler, which caused operational difficulties on one occasion when it stopped working and no one knew how to start it again (Ref. Utne)

The installation of the biogas boiler took place at the same time as the regular reconstruction works at the sewage plant. The timing was a challenge because the construction process led to some delays in the installation of the boiler. The development of the biogas boiler and the reconstruction of the sewage plant required collaboration with the client, and made it necessary to get involved with their existing organization, this was challenging for Statkraft varme (Ref. Moen).

The energy production from the biogas boiler is less than was expected at the start of the project. The aim was 6 GWH, the actual result after the biogas boiler became operational is 4 GWH. The reasons for this are uncertain but it seems likely that the sewage plant is receiving less waste water for treatment than expected. However it is likely that the expected population increase in Trondheim will mean an increase in the amount of waste water being delivered to the sewage plant and an increase in the biogas being produced. The Ladehammeren Sewage plant is a small operation within the district heating system and Statkraft varme are pleased with the amount of energy produced in relation to the size of the plant (Ref. Utne).

6.4 Kolstadflaten Housing Cooperative – Intelligent Metering

Kolstadflaten housing cooperative is located south of the city of Trondheim. The housing cooperative is part of the suburb of Kolstad which is one of the city's most densely populated areas. There are 481 dwellings within the housing cooperative, which primarily consists of low-rise apartment buildings located around 6 courtyards. Each courtyard has a small children's playground. The first residents moved into apartments in 1970. The housing cooperative conducted an extensive rehabilitation between 2007 and 2008.

Kolstadflaten housing cooperative, Photo TOBB

6.4.1 What has been done and why?

The first the visions of the project were formulated by Fartein Breitaset from COWI and Trond Sundseth from Statkraft varme with support from TOBB. Initially, the ambitions were more extensive, but the project eventually became an exercise on how to ensure an optimalised installation process. The intention was initially that residents should be able to, through the use of meters, continually follow their own energy use and through this activity become motivated to reduce their use of electricity. However, there was a problem concerning the ownership of the data (customer info) that stopped the project from being more ambitious. The project group was unable to solve this. The main focus became getting as many meters installed as possible in the least possible time. Technical installation was itself the in focus. They have installed two-way meters for the measurement electricity in all 481 households in the housing cooperative.

6.4.2 Training and Operation

TrønderEnergi are responsible for the service and operation of the meters. The planning process was long, but there have not been any particular technical problems associated with the installations after they were taken into use.

6.4.3 Advantages and Barriers

The system was intended to be connected to resident's personal computers via the Internet, and TOBB is disappointed about the failure to achieve this (Ref. Skippervik). The measuring of household electricity use works well, but TOBB had hoped that this information would be used for more than making sure that householders receive bills for the correct amount of electricity used. They had hoped that information about energy use would be available to residents through personal computers (Ref. Skippervik). This information was intended to create customer awareness and motivate them to use less electricity. It would have been useful to present the response of residents to the technology installed, to discuss whether their understanding of their energy use had changed, and whether this had motivated them to reduce their energy consumption. However this would have required access to personal data which is not possible within the parameters of this report.

Kolstadflaten housing cooperative, Photo Eiendomsmegler 1

6.4.4 What have We Learned?

The implementation of two-way meters for the measurement electricity (AMR) in Norway is problematic because there are a number of things which are not clear in relation to ownership of the data (customer information). If Norway is to install this kind of meters it is important to develop a plan and regulations for customer feed-back developed. The lack of a plan stopped this project from being more ambitious. However, the installation process has been optimal and useful knowledge has been collected. This information may be useful in future projects.

7 Svartlamoen Boligstiftelse (Housing Foundation)

Svartlamoen 2011, photo Brendeland and Kristoffersen

Svartlamoen in Trondheim is Norway's first urban ecological neighbourhood. Svartlamoen housing foundation has the formal responsibility for managing and maintaining rental properties in Svartlamoen. The Svartlamoen housing foundation was established by the Trondheim municipality in 2001. Along with Svartlamoen cultural and economic foundation, the housing foundation runs Svartlamoen as ecological neighbourhood according to the municipality's definition, which says that Svartlamoen should be an alternative neighbourhood with room for experimentation. This applies to the housing, social interaction, participation, ecology and energy use, municipal services, art, culture and economic development.

Svartlamoen housing foundation manages approximately 130 units, including communes, apartments in larger apartment buildings and houses. Most buildings are currently owned by the municipality of Trondheim. The building stock varies in age and standard. The oldest buildings are from the 1890's, the newest was built in 2005.

7.1.1 What has been done and why?

According to the SINTEF report from 27.08.2007 the solution proposed for Svartlamoen, which would have been in compliance with the ECO-City concept was solar collectors, a biogas boiler, and reserve heat from the district heating system during the coldest months of the year. The solar collectors would provide energy that would be used in the heating system, and for the heating of water for everyday use. It was suggested that 24 apartments participate in the pilot project, with a total areal of 960m2. In addition 5 cultural and commercial buildings were also suggested participants, with a total area of 3000m2. None of the aforementioned energy solutions were installed.

The Svartlamoen housing foundation is no longer part of the ECO-City project. The initial decision to participate in the project was made quickly because it fitted into the ideological concept which is important to how the neighbourhood is run. In the beginning there was some resident participation in the project because the residents were interested in the possibility of installing under floor heating and solar panels. However the building stock was in such bad technical and physical condition that the housing foundation could not meet the technical requirements that were set by the ECO-City project. The housing foundation needed to rescue the buildings as a whole. Some windows have been changed from single to double glazing, and insulation was also added where there was a problem with drafts. They are today struggling to reach energy standards set in the 1970s. The housing foundation officially withdrew from the ECO-City project in 2009–2010.

7.1.2 Advantages and Barriers

Svartlamoen, Photo Framtidens byer

The main barrier to continuing participation was that the ECO-City project rules for technical standard were inflexible and not easily adaptable so that old, badly maintained buildings could be included in the project. In addition the housing foundation's economy came under pressure, because it relies on rental income and this is approximately 50% less than normal levels in Trondheim. ECO-City uses the term "eligible costs" in relation to investments to be made. This means that not all of the costs connected to a proposed installation/ energy saving measure are eligible for financial support. In the case of Svartlamoen this means for example that the switch from electric heating to waterborne energy is not eligible for support. The biogas boiler connected to a (non-eligible) waterborne heating system is on the other hand eligible for support (Ref. SINTEF 2007). The housing foundation also depends on the residents voluntary contributions, both in terms of funding and as a workforce. At the present time all the available funds are used on preventing the building stock from falling apart (Ref. Solberg). It was not feasible for the Svartlamoen housing foundation to participate in the technical activities stipulated by the ECO-City project. The participant's idealism was not enough to realise the energy saving measures proposed at the beginning of the ECO-City project.

The description by the housing foundation of the reasons why they withdrew from the project matches the description given by Trondheim Municipality's project manager. He described the Svartlamoen project as the least successful because they were unable to complete it (Ref. Lundli). The ecological profile of the neighbourhood fitted with the aims of the ECO-City project, but the housing foundation did not have sufficient equity to make continued participation possible.

7.1.3 What have We Learned?

The manager of the Svartlamoen housing foundation suggests that they have gained knowledge through their participation in site-inspections and meetings. The manager could not definitely say that they should not have participated, but experience with the project showed them that they could not even come close to the requirements set by ECO-City (Ref. Solberg).

8 Discussion and Conclusions

The report considers whether the aims of the initial ECO-City project were achieved from the perspective of the end-users who participated in the qualitative survey in the autumn 2012. The actual energy figures provide background for the response of the informants, but the figures are not the focus of this report. Achievement may be also measured in relation to other aspects associated with ECO-City project, such as user satisfaction, user comfort, safety, use friendliness, operational success and the challenges faced during the developmental process. Eco-City aims for energy efficiency and energy savings and the aforementioned aspects are not, as is the case with energy figures, instantly associated with energy efficiency. However it is suggested here without them it is difficult to see that energy efficiency can be achieved. These aspects can support, influence and potentially undermine the energy saving aims of the project. It is therefore important to highlight how they have played a role in the ECO-City project.

The ECO-City project aimed to achieve energy savings in buildings and eco-buildings through an optimal cost effective reduction of energy consumption. This was to be done using several energy sources, ones which provide the most energy effective mix in each community. The aim was also to look beyond the impact on each eco-building and to look at the impact on a community level. The discussion and conclusion will consider whether these 2 main aims were achieved, as well as aspects which are central in the 13 original projects. The primary focus of this section is what has been learned during the ECO-City project in Trondheim.

8.1 Report limitations

The "professional end-users" in the 13 pilot projects in Trondheim are the focus of this report. Individuals who, because of their professional roles, either as project managers or as operational personnel, have been, or are, involved in the development and/or operation of the technical installations which have been completed in within the ECO-City project. The initial plan for the user-evaluation suggested also gathering information from residents in the 4 TOBB housing cooperatives and in Miljøbyen Granåsen, and other end-users such as pupils at the municiple schools. However this would have required personal information which the ECO-City does not have access to. The proposed "thick description" of the pilot projects would have provided detailed insight into everyday use, and provided social background with which to understand the figures associated with actual energy savings (Geertz, 1973). Trondheim is a specific social and climatic example within both a regional and Norwegian context. The analysis of the reasons for the differences and similarities in, for example, energy savings or operational challenges would have been more robust with a more detailed account of the social context. It is recommended here that user-evaluations play a more central role in the next generation of EU projects which have a focus on energy efficiency. If we are to learn more from successes and failures associated with for example user satisfaction and the challenges faced during the developmental process then a more in-depth is necessary.

ECO-City has been as catalyst for the commissioning and installation of both tried and un-tried technology, but the technology itself has its own agency and this agency in collaboration with the project developers/managers, technical engineers and caretakers has implications on energy efficiency. Agency implies happenings which are intentional, rather than related to physical or natural events. Agency is also relational, for every agent there is a patent who is acted upon. Agents are recognized because something is changed in the non-causal physical world around us (Leach, 2007). In this section of the report the impact of the technical agency in collaboration with the end-user group will be highlighted. A product/technology is not just understood by looking at the intentions of the designer or the properties of the product. It is also important to consider how it is perceived, interpreted and used (Fallan, 2007).

8.2 Project Dynamics

Between 2008 and 2011 Trondheim Municipality reduced its energy use in municipal buildings by 7, 2 %, and it aims to reduce its energy efficiency by 10 % by the end of 2012 (Adresseavisen 30.10.2012). On a municipal level Trondheim is among the best energy savers in Norway. It is suggested here that Trondheim's participation in the ECO-City project is a factor which has influenced this result. This report shows that participation was motivational, encouraging actors in the municipality's Environmental Department to set in motion energy saving activities at an earlier stage than would have perhaps been considered desirable without the funds, demands, inspiration and encouragement provided by ECO-City. However it is also possible to say that ECO-City has also enjoyed the positive momentum provided by the enthusiasm of the municipality's project managers. The positive momentum also includes the activities that were already being planned by the municipality, as well as the energy effective operation of municipal buildings that was established practice. During the interviews with both project managers and the operational personnel, questions about the operation of the project, often returned to the importance of the effective follow-up which is provided by the municipality's operational centre, and the knowledge and interest provided by the caretakers who work on a day to day basis with the buildings involved in the ECO-City project. Trondheim Municipality in a recent article on energy saving in the local paper also base much of their success on the enthusiastic efforts of their employees (Adresseavisen 30.10.2012). ECO-City's success relies on the operational network already established within the municipality. The results achieved by ECO-City can therefore not be understood alone, they should be seen within a wider operational and social context**.** Statkraft varme also had an effective system for control and operation.

When working within an operational network, such as is established within the municipality and Statkraft varme, the sharing of information on all levels is a success criteria. Informants suggest that information has been effectively shared both during the installation process, and after the technology was installed and taken into operation. The biogas boiler at the Ladehammeren Sewage plant is the only example where information was initially not shared effectively, leading on one occasion to problems getting the biogas boiler started again. However there is still potential for greater sharing of information during project development. Access to information is empowering, it encourages ownership, understanding, usability, user friendliness and effective operation. The project managers, technicians and caretakers may be considered actors within social, organisational and physical networks, where the focus is energy efficiency. Actors construct networks through an accumulation and execution of power, but the power is not always distributed evenly (Fallan, 2007). In the wider ECO-City project there are a number of networks where power may be associated with other aspects, such as access to the EU. This is a simplification of what is complex system where amongst others bureaucracy, economy and access to information all play a role, and which would require a more in depth analysis than is possible here. It is mentioned here to provide context with which to understand activity in Trondheim. Within the projects in Trondheim access to information is a power factor. Sharing information during the developmental period would not necessarily have hindered all problems encountered after installation, such as the limitations associated with the ventilation capacity at Rosenborg School, but there are examples within the ECO-City project where greater involvement during project development could have made a difference. For example information, both verbal and visual, could have made the transition from installation to everyday use of meters at the Tonstad housing cooperative go more smoothly.

The 4 organisations, Trondheim Municipality, Statkraft varme, TOBB and Heimdal Bolig AS regarded participation in the ECO-City project as being positive for their image. It fitted with their declared aims and provided an arena where they could present and realise these aims. For example Statkraft varme operates in a market where the production, deliverance and sale of energy are increasingly competitive. Finding new business models and creating advantages within the market is important to them. In the case of Heimdal Bolig AS, ECO-City fitted with their plans to be at the forefront of the housing market. Participation was therefore not just about testing and installing new energy efficient technology, it was also about gaining access to new markets and presenting an image that is acceptable to these markets.

8.3 Craftsmanship and Knowledge

In the Miljøbyen Granåsen project the demands imposed by the passive house standards have resulted in a greater interest in craftsmanship and building quality amongst the construction workers. The project manager Kristian Stensrud suggests that the houses built have an exceptionally high standard. Heimdal Bolig AS already had plans to build passive houses before involvement with ECO-City became a possibility and it is not suggested here that the interest in craftsmanship is primarily a result of participation in the ECO-City project. However it does point to the wider implications of the energy requirements faced by the Norwegian building industry. The extra training that the construction workers received at the start of the Miljøbyen Granåsen project has given them skills and experience that other construction companies are only just starting to acquire, placing them ahead of the rest of the market (f. Woods, 2013). The building at Miljøbyen Granåsen has taken place under a tent. This also provided a learning experience for the construction workers involved, because attempts to work without a tent resulted in ruined materials and a costly rebuild. Working under a tent provides a more comfortable working environment, and this resulted in Miljøbyen Granåsen being one of the most popular building sites in Trondheim. Achieving energy savings therefore has implications for craftsmanship, knowledge and the working environment. Heimdal bolig AS and the construction workers who built the houses, have the potential to become active agents in the passive house industry. Their access to information gives them the opportunity to push the market forward.

Being ahead of the market in knowledge, skill, and attention to passive house standards resulted in house prices at Miljøbyen Granåsen that were slightly above the rest of the market. The high building standard and quality of craftsmanship is not knowledge which the property market is aware of. In addition the general public has little knowledge about what a passive house is and what it means to live in one. The property market and its customers require more knowledge about these 2 factors. Heimdal Bolig AS and ECO-City could have disseminated to a wider audience the ideals of the project and its implications for residents and the public in general. However although the average house buyer is not aware of the requirements set by the Norwegian building standards (TEK7, TEK10, TEK15) or why they have been set, it is important that they are in place to push the market forwards towards greater energy efficiency.

The ECO-City project has involved both tried and tested technology and new technology. Tried and tested technology has its own agency. It has positive momentum based on existing knowledge amongst project managers, technicians and caretakers. There already exist routines for the operation and follow up for example ground-water heat pumps and biogas boilers. In supporting the use of this kind of technology ECO-City has built upon established expectations of what it required of energy efficient technology. New technology has provided greater challenges, both in relation to the cost of development, and the time it has taken to develop the technology and solve the problems associated with it after installation. Successes and failures have implications for future use and how it is presented to the rest of the market.

8.4 District heating and solar collectors

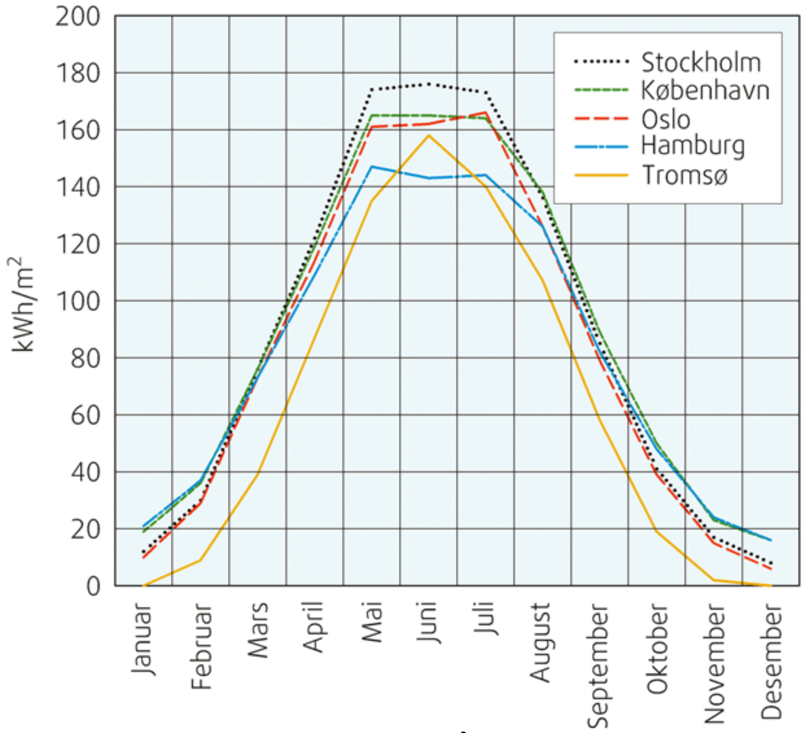
Trondheim Municipality's policy is that as many new building projects as possible should be connected to the district heating system. Connection to the district heating system may be considered a physical and technical realisation of the whole community design approach suggested by the initial ECO-City development project. All of the municipal projects which are part of ECO-City are connected of the district heating system, and support therefore this ideal. However, the district heating system is not the primary source of heating in any of the 4 projects. The district heating system supplies extra heat during the coldest periods of the year. It is not a declared aim in any of the 4 projects, but it may be suggested that has been important to limit dependence on the district heating system. The district heating system has a limited capacity and pressure on this capacity, such as during cold months of the year, has implications for the environmental impact of the system. Statkraft varme burn oil and gas during the coldest periods of the year, when there is greatest need from the district heating system. Energy savings therefore also imply reductions in the use of the district heating system.

Private homes are connected to the system, for example Miljøbyen Granåsen and TOBB housing cooperatives. The meters installed in housing cooperatives help to reduce energy consumption and in some cases this energy is supplied by the district heating system. Amongst some of Miljøbyen Granåsen's residents there exists scepticism to the district heating system. It is suggest that it is not an environmentally friendly as the municipality suggests when it insists that new housing projects are connected to it. There were two reasons given for this scepticism, firstly the district heating system does not just burn household and industrial waste. During cold periods of the year oil and gas are burned. The second reason for scepticism amongst some residents at Miljøbyen Granåsen is that the heating system loses heat in from the pipelines before it reaches the houses. This aspect was not discussed with the project management and it is unclear how great the heat loss is.

Statkraft varme has reduced the amount of oil and gas which is used and aims to further reduce this amount. Two of the projects associated with ECO-City are directed towards achieving a reduction. The seasonal storage of waste and de-bailing machine at the Heimdal District Heating plant and the biogas boiler at the Ladehammeren Sewage Plant are intended to increase capacity and reduce dependence on oil and gas. However public scepticism still exists. Wider dissemination of information about the reduction in the use of oil and gas through new technical installations would help to reduce public scepticism. Dissemination of information could also usefully take place within Trondheim's ECO-City community. The scepticism to the district heating system shows that there is only limited internal exchange of information between the 12 ECO-City projects.

A further reason for scepticism to the district heating system amongst some Miljøbyen Granåsen residents is that the initial project proposed that solar collectors would be installed on the southern facades of the houses. There was some disappointment about this and it was suggested that this would have been a more energy efficient solution (Ref. Stensrud). However this information gains an extra dimension when it is considered alongside the feedback from the project manager associated with Ranheimsveien 149. He was disappointed with the energy savings associated with the solar collectors installed on this building. He suggested that the technology was expensive and the energy production low. The low energy production was associated with the climate in Trondheim. The pay-back for the solar collectors is expected to be a long one (Ref. Lindtorp).

These two examples raise the question as to whether solar collectors are an energy effective solution or not. In the SINTEF byggforskserien 552.445 it is stated that the annual solar radiation in Norway varies from approximately 700 kWh/m2 in the north, to ca. 1100 kWh/m2 in the south. There are large variations between summer and winter, but that it is possible using solar collectors to utilize a part of solar radiation for heating purposes (SINTEF 2011). The total solar radiation in Trondheim is approximately 4% lower than in Oslo in May and June, and 10-15% lower in July / August. It is during these months that solar collectors are most useful. Incoming radiation in Oslo is the same as in Copenhagen, and Denmark is well-known for its use of solar collectors. The solar collectors installed in Ranheimsveien 149 have only been operational a short period of time, this and the poor summer in 2012 can have implications for the results. It is possible that there is something wrong with the system or coordination with the rest of the heating system (Ref. Simonsen).



Total monthly solar radiation on the horizontal plane (kWh/m^2) for Stockholm, Copenhagen, Oslo, Hamburg and Tromso, Byggforskserien 552.455

The results from Ranheimsveien are influential within the municipality. The ECO-City projects have not been actively presented outside the ECO-City consortium and have only limited impact within ECO-City's Trondheim community, but the results have had made an internal impact within the individual organisations. Trondheim Municipality has actively used ECO-City projects to test new technology and systems, which have then been used in other municipal projects outside ECO-City. The results from Nardo School are an example of this. The negative results from Ranheimveien 149's solar collectors have resulted in solar collectors being dropped from new projects. It is not known here whether the decision to not include solar collectors in the new Åsveien School is only based on the results from Ranheimsveien, this seems unlikely, but its negative influence does exist. It is not only success stories which influence the development of energy efficient solutions. Technology can also have negative agency, and experiences with this should be presented and discussed with a wide audience if the influence/agency is to be constructive.

8.5 User Awareness

One of the aims associated with installing meters in the TOBB housing cooperatives is increasing user-awareness. Energy use has been reduced in all the housing cooperatives which were part of the ECO-City project, but it is unclear whether there is always a direct correlation between this reduction and greater user awareness. In the Ustmyra housing cooperative meters were installed and the apartment buildings were rehabilitated. Energy savings may be related to both aspects. At the Kolstadflata housing cooperative energy savings are only based on having installed two-way meters in all 481 households. However it is suggested here that the installation of meters would have had an even greater impact on user-awareness if the information about energy use had been made directly available to householders through personal computers. The two projects point to the installation of meters encouraging energy savings, but they also suggest that a greater exchange of information between the meters and the residents would have encouraged even better results.

TOBB manages and administrates a network of 100 housing cooperatives in and around Trondheim. Runar Skippervik the project manager suggests that other housing cooperatives have shown an interest in measures used in the 4 ECO-City projects and the energy savings achieved. This has had a positive effect on their desire to rehabilitate. TOBB because it is already part of an extensive social network within Trondheim may potentially spread the results associated with ECO-City to a large number of people. Information about the energy savings associated with the ECO-City project is also spread by the residents themselves. Although there is no information to suggest that residents were aware of the role that they play in the ECO-City project, they do have potential as ambassadors. It is suggested here that it would be relevant to gather more information about residents experiences within the ECO-City project.

Customer/user safety and satisfaction are challenges which exist in several of the projects. These aspects are present in the municipal projects, and came across most clearly due to challenges related to air-quality. The capacity of ventilation system at Rosenborg School was under dimensioned during the planning phase this has resulted in problems for both staff and pupils. It is not possible to just accept that the problem exists, it has to be solved and this continues to cause problems for the technical and caretaking staff. Energy efficient buildings require air-tightness. Air-quality and ventilation are challenges which have to be solved if we are to achieve customer satisfaction in energy efficient buildings. It is unclear how great the satisfaction or dissatisfaction which the buildings involved in the ECO-City project is because the limitations associated with the user-evaluation which took place. Achieving the depth of analysis associated with a broader qualitative end-user survey is as was mentioned earlier recommended in further EU projects concerning energy efficiency.

Customer safety and satisfaction were also important during the development of the refrigeration system installed at St. Olav's Hospital. Statkraft varme have used a lot of time and resources in developing a system which would deliver stable and effective cooling to the hospital. Health and comfort rely on the system functioning effectively. Customer satisfaction is understood as being achieved because the staff and patients are not aware that there have been any changes in the system. The transference from the old to the new system has gone smoothly.

8.6 The Community Based Approach

Findings associated with the final report show that the pilot projects achieved the RES and RUE levels proposed in the initial description of work. They also point to the importance of the community based approach when achieving the expected energy reductions. However there are four separate organisations involved and thirteen pilot projects. Each of the pilot projects has worked individually to achieve the aims set out by the initial project. Technically and geographically the community wide ideal is in place, but on the social level if we look beyond the activities of the project managers there is a lack of awareness in relation to the other partner's activities, and a general lack of awareness of within the city of Trondheim amongst the local population to the existence of the ECO-City project and what it has achieved. A community approach requires a level of social involvement; this would encourage increased awareness amongst a broader section of the population in Trondheim, increased end-user involvement and finally to even better results in relation to energy reductions.

The community form of the project has a more compact geographical form than is the actual geographical situation within the city of Trondheim. Trondheim is a small city population-wise but it has relatively large geographical spread. It is unclear at this time why this geographical form was chosen, but it has created limitations on the development of the project. For example projects were chosen not just because of their relevance to the aims of the ECO-City project, but also because of them fitting within the predefined geographical area established by the project application. A bioenergy plant at Leinstrand School was not included because it was outside the ECO-City area. The bioenergy plant was opened this spring. The initial project proposal aimed to include a bioenergy building.

It is suggested here that greater focus on dissemination would have allowed the wider population within Trondheim access to the aims associated with ECO-City and what has been achieved within the 12 completed projects. Giving the population in Trondheim access to information about the project was one of the initial aims of the ECO-City project. There is a general tendency in research projects to wait until the final results have been achieved or until the final report has been written to begin with dissemination, by this time it is often too late because project finances are limited. Education of the end-user groups associated with the 12 projects also plays a role here. The operational staff has information about the projects and the energy aims, but they are not the only end-user group**.** There are numerous other end-user groups who could have been included in the information network associated with ECO-City. Residents, school pupils, municipal employees, Statkraft customers all would have benefitted from user-education and the exchange of information. Information is empowering and the interest that it creates has the potential to achieve further cost effective reductions in energy consumption.

8.7 What have we learned?

The main focus of this report has been to discover what the different 4 different organisations, 13 projects, project managers, technicians and caretakers have learned through their participation in the ECO-City project. In each of the 13 projects we have considered what has been done (technology and installations), the training and operation and the advantages and barriers associated with these activities. What was learned was also presented in relation to each individual project; however there are some main themes and these have been presented in the previous section. Importantly energy efficient technology cannot learn; it is the people associated with the technology who go through a learning process. Energy savings and efficient operation cannot be achieved without a learning process and success cannot only be measured in relation to the figures associated with energy savings. Success should also be measured in relation to social aspects associated with the ECO-City project, for example user satisfaction, use friendliness, and the challenges faced during the developmental process. The aspects presented in the previous section which have influenced the energy saving aims of the ECO-City project can, it is suggested here, be summed up within two main categories:

Success factors

- Participation has been motivational, encouraging actors to set in motion energy saving activities at an earlier stage. It should also be pointed out that that ECO-City has enjoyed the positive momentum provided by existing knowledge and enthusiasm amongst many of the participants.
- ECO-City's success relies on the operational network already established within the participating organisations. The results achieved by ECO-City should be understood within a wider operational and social context.
- The sharing of information on all levels is an important criterion for success; both during the installation process, and after the technology was installed and taken into operation.
- Participation was not just about testing and installing new energy efficient technology, it was also about gaining access to new markets and presenting an image that is acceptable to these markets. ECO-City provided a relevant image for particpants
- Passive house standards have resulted in a greater interest in craftsmanship and building quality amongst the construction workers.
- The extra training that the construction workers received during the Miljøbyen Granåsen project has given them skills and experience that puts them ahead of the rest of the rest of the local construction industry.
- Working under a tent provides a comfortable working environment. Achieving energy savings has implications for craftsmanship, knowledge and the working environment.

- The installation of meters in housing cooperatives encourages energy savings. **However** a greater exchange of information between the meters and the residents would have encouraged even better results**.**
- The ECO-City project has involved both tried and tested technology and new technology. The tried and tested technology provided the project with positive momentum, built upon existing knowledge and routines. The new technology provided greater challenges.

Potential improvements

- There are numerous other end-user groups who could have been included in the information network associated with ECO-City. Achieving the depth of analysis associated with a broader qualitative end-user survey is recommended in further EU projects concerned with energy efficiency.
- The general public has little knowledge about what a passive house is and what it means to live in one. Being ahead of the market in knowledge, skill, and attention to passive house standards resulted in house prices at Miljøbyen Granåsen that were slightly above the rest of the market.
- There exists public scepticism to the district heating network. Wider dissemination of information about the reduction in the use of oil and gas through new technical installations would help to reduce public scepticism. This should take place within Trondheim's ECO-City community because there is only limited internal exchange of information between the 12 ECO-City projects.
- It is not only success stories which influence the development of energy efficient solutions. Technology can also have negative agency, and experiences with this should be presented and discussed with a wide audience if the influence/agency is to be constructive.
- Customer/user safety and satisfaction are challenges which exist in several of the projects, this came across most clearly in projects where air-quality was a challenge.
- Technically and geographically the community wide ideal is in place, but on the social level of there is a lack of awareness the other partner's activities and within the city of Trondheim in general.
- Projects were chosen in Trondheim not just because of their relevance to the aims of the ECO-City project, but also because of them fitting within the predefined geographical area established by the project application.

The ECO-City project focuses on 2 main aims, achieving a cost effective reduction in energy consumption, and doing so on a community wide level. The combination of the 2 implies an association between them. It is suggested here that the first aim associated with energy consumption has the potential for even better results, if the social implications of community wide approach had been more in focus. It is suggested here that the planning and use of user-evaluations should play a more central role in the next generation of EU projects which consider energy efficiency.

Access to information is empowering; it encourages ownership, understanding, usability, user friendliness and effective operation. Participants in the 13 projects are participants in social and technical networks where the focus is energy efficiency. Within these networks actors have exchanged information about the operation, history, success and failures associated with this technology. Through this exchange of information they have encouraged the positive and negative agency of the technology, and have contributed to the energy savings associated with ECO-City. Access to information, an efficient operation centre and a pre-existing interest in achieving energy savings have therefore been important success factors within the ECO-City project.

The information accumulated within the ECO-City project could usefully have been exchanged with a larger number of people. It is suggested here that greater focus on dissemination would have allowed the wider population within Trondheim access to the aims associated with ECO-City and what has been achieved within the 12 completed projects. The dissemination of the results associated with the ECO-City project within the pilot projects and amongst the wider population in Trondheim provides useful information for those interested in the challenges associated with energy technology. Further dissemination would help to increase the relevance of a project like ECO-City because presentation of the facts provide information about what an EU project can do for a city like Trondheim, and encourages further energy saving activity amongst the local population.

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11 Attachments 1: Interview guides

Intervjuguide 1 – ECO-City

Vi skal avdekke:
Hva er installert – vi vet det grunnleggende, trenger mer detaljer om når osv.
Hvordan brukes det
Hva er nytteverdien
Hvordan skal man informere om drift av det som er installert

Informasjonen om informanten:
- Stillingsbeskrivelse
- Hvor lenge har du jobbet med dette
- Rollen i prosjektet/ ECO-city
- Beskrivelse av valgte miljøtekniske løsninger / miljøkonsept
- Forhold til prosjektet som skal beskrives

Prosjektinformasjon: Generell informasjon om sted/prosjekt
- Hva er det bolig, skole, annet?
- Størrelse, M2, byggeår, arkitekter/prosjekteringsteam, byggherre,
- Programmeringsforutsetninger: Antall arbeidstakere? Antall brukere?
- Når ble anlegget tatt i bruk?

Intensjoner:
- Hvem var det som i størst grad formulerte visjoner/intensjoner for teknologien som ble installert? (ark? BH? Kommunen?)
- Miljøtekniske intensjoner, begrunnelse for valgt konsept
- Spesielle intensjoner for virksomheten utover de miljøtekniske føringene?

Installasjon
- Hvem installerte anlegget/ teknologien?
- Har du vært involvert i installasjonsprosessen?
- Møtte dere spesielle utfordringer under og rett etter montering?
- Fikk du opplæringen/informasjon i forkant av installering eller etterpå?
- Hvem fikk opplæringen i drift av anlegget?

- Er det laget en plan for opplæring?
- Hvor mange er involvert i driften av anlegget?
- Er du fornøyd men din og andres opplæring?
- Hvordan kunne det eventuelt utbedres?
- Har dere fått tilbakemeldinger fra andre om driften/opplæringen?
- Hva slags råd ville du gi andre som skal installere den samme teknologien?

Drift

- Hvem utfører service/vedlikehold?
- Har det vært tekniske problemer?
- Har dette vært krevende? Tid/kostnader?
- Har det vært behov for å endre anlegget, er det en mulighet i framtiden?

Energiutbytte

- Hva levere anlegget energi til?
- Hva er de største miljøgevinstene?
- Stemmer de reelle besparelser/ effekter med det dere ble forespeilet?

Måling

- Hvem er det som foretar måling av resultatene?
- Er dere fornøyd med resultatene?
- Er det rom for forbedring/ eventuelt hvor?
- Er det planlagt flere tiltak for å redusere energiforbruket?
- Hva?
- Hvorfor?
- Er dette resultat deltakelse i ECO-city?

Sosial kontext

- Har du tidligere vært opptatt av energiforbruk / miljø?
- Er du mer opptatt av det etter du begynte å jobbe med ECO-city?

- Hva mener dine kolleger? Er dette noe tema dere er opptatt av?

Comfort (relevant i noen prosjekt?)

- Ville du beskrive bygningen som komfortabel?

- Hva er avgjørende for opplevelsen? (Hvorfor / hvorfor ikke?)

- Hva betyr komfort for deg?

- Hvordan opplever du luftkvaliteten ("tett luft", tørr luft, vondt i hodet osv.)? Hva gjør du dersom du opplever at det er tett luft?

- Opplever du støy fra noen av installasjonene? I så fall hvilke? Gjør du noe med dette? (reduserer styrke, skrur av etc.)

- Opplever du akustikk/etterklangstid som behagelig?

Oppsummerende fra brukerne

- Ble dine forventinger om en god arbeidsplass oppfylt?

- Hvilke kvaliteter ved bygningen betyr mest for deg?

Intervjuguide 2 – ECO-City

Hans Einar Lundli, Trondheim kommune 19.10.2012

Vi skal avdekke:
Hva er installert
Hvordan brukes det
Hva er nytteverdien
Hvordan skal man informere om drift av det som er installert
Hva har vi lært

Informasjonen om informanten:
- Stillingsbeskrivelse
- Hvor lenge har du jobbet med dette
- Rollen i prosjektet/ ECO-city

Beskriv dine/ kommunens begrunnelser for deltakelsen i ECO-City

Kan du kort beskrive prosjektene som er med i ECO-City og hvorfor de ble valgt?
- Miljøtekniske intensjoner, begrunnelse for valgt konsept
- Spesielle intensjoner utover de miljøtekniske føringene?
- Hvilke prosjekt har fungert best og hvilken har vært minst vellykket?
- Kunne flere prosjekter vært med i ECO-City?
- Var hele prosjektet stort nok? Eller for stor?

Hvem var det som i størst grad formulerte visjoner/intensjoner for teknologien som ble installert? (ECO-City, Kommunen, Andre)

ECO-City har en "Whole community design approach" hvordan har dere i kommunen jobbet med det? Har dette vært et viktig aspekt i prosjektet/prosjektperioden?

Utfordringer
- Møtte dere spesielle utfordringer under planlegging, installasjon og rett etter montering?
- Fikk du/ ansatte tilstrekkelig opplæringen/informasjon om teknologien som ble installert?
- Er du fornøyd men opplæringen?
- Hvordan kunne det eventuelt utbedres?
- Hvor mange er involvert i driften av anleggene?
- Hvor mange personer er berørt av ECO-City prosjektet?
- Hva slags råd ville du gi andre som skal installere den samme teknologien?
- Hva er de største fordelene med deltakelser i ECO-City?
- Hva har vært de største hindringene?

Har det vært tekniske problemer?
- Har dette vært krevende? Tid/kostnader?
- Har det vært behov for å endre noen av anleggene, er det en mulighet i framtiden?

Energiutbytte

- Hva er de største miljøgevinstene?
- Stemmer de reelle besparelser/ effekter med det dere ble forespeilet?

Måling

- Er dere fornøyd med resultatene?
- Er det rom for forbedring/ eventuelt hvor?
- Er det planlagt flere tiltak for å redusere energiforbruket i kommunen?
- Hva og hvor?
- Hvorfor?
- Er dette resultat av deltakelse i ECO-city?

Oppsummering

- Hva hadde du de største forventninger til?
- Ble dine forventinger oppfylt?
- Er det noe dere angrer på?
- I ettertid er det noe du ville endret?
- Hva har dere lært?
  Er dette noe som dere kan bruke i andre sammenhenger/prosjekter?
- Er dere interessert i å delta i flere EU prosjekter?
- Hva slags råd ville du gi andre som vil delta i slike prosjekter?
- Har ECO-City lykkes med sin "Community design approach"?

Sosial kontekst

- Har du tidligere vært opptatt av energiforbruk / miljø?
- Er du mer opptatt av det etter du begynte å jobbe med ECO-city?

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