TREES Training for Renovated Energy Efficient Social housing

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Section 3 Case studies

3.1 Gårdsten - Sweden

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Partners

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Content

Abstract

A residential building area in Gårdsten, Göteborg, has been renovated as part of an EC THERMIE project. The aim is to demonstrate a comprehensive integrated renovation concept comprising energy conservation measures and utilisation of solar energy, as well as improved architectural and social conditions, making typical blocks of flats from the 70's more attractive. The building area, owned by the municipal housing company Bostads AB Gårdsten, comprises 1 000 flats in 3-5 floor concrete element buildings, out of which 255 flats in three blocks have been renovated. Innovative solar features are: prefabricated roof modules with integrated water collectors, glazed balconies and solar air collectors combined with a double envelope walls. Traditional measures together with the solar features and individual metering have resulted in about 40% energy savings for heating, ventilation and domestic hot water. The construction ended in 2000 and this report is focused on the operational experiences 2001 to 2004.

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The initial project team comprised Stina Fransson, Rune Lindh, Sofia Kaså and Michael Pirosanto, Bostads AB Gårdsten, Christer Nordström, Christer Nordström Arkitektkontor AB, Jan-Olof Dalenbäck, CIT Energy Management AB, Anders Bernestål, Ing.byrå Andersson & Hultmark AB, Gert Lönnroth, Bergsäker Konsult AB, Lars-Åke Larsson, Partille Elkonsult AB and Håkan Lindhén, Mårtensson & Håkansson. SKANSKA was the main contractor.

1. Introduction

In 1993 "Solar Energy in Building Renovation" was initiated within the IEA Solar Heating and Cooling Program. The work was concentrated on documentation and dissemination of suitable solar renovation concepts and resulted in a number of publications and sample projects. A major dissemination effort was a brochure package published by James & James (Boonstra et al, 1998).

This case study report describes a demonstration project that builds on the experiences from the IEA work, as well as experiences from previous national demonstration projects. The project was initiated at the time for the call for targeted projects for the THERMIE program in 1996, and has been carried out with financial support from EC (SHINE - BU/1051/96).

The owner of the buildings, Bostads AB Gårdsten, is a new municipal housing company formed to develop the Gårdsten area regarding facility management, as well as from a social point of view (poor tenant service, low or no incomes, high part immigrants, etc). The buildings lacked maintenance and about 30 % of the flats were not occupied in 1997.

Investigations regarding suitable renovation measures and financing were carried out during 1997 and 1998; the board took a positive vote and call for tenders was developed late 1998.

The construction for the so called “Solhus” project started early 1999, the first block was commissioned early 2000 and the whole project including initial evaluation was finalised in 2001. The project and an initial evaluation have been presented by Dalenbäck and Nordström (2001). The applied measures have now been in operation for four years. This report is an elaborated version of a paper presented by Pavlovas and Dalenbäck (2005).

2. Before renovation

The Gårdsten area is divided in three parts, East, North and West Gårdsten, each comprising about 1 000 flats. The demonstration project comprises renovation of three blocks with 255 flats and close to 19 000 m² of heated floor area in West Gårdsten. Fig. 1 shows a site plan.

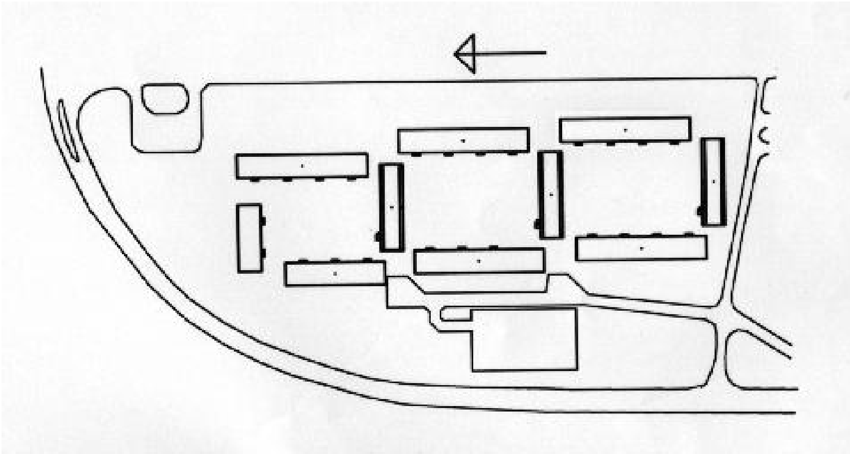

Fig. 1 Site plan showing the Solhus project comprising three blocks with 10 buildings.

These three blocks comprise ten buildings, three high-rise buildings with 1+5 storeys, facing south, and seven low-rise buildings with three storeys, one facing south and six facing east/west.

Electricity, heat and water are supplied via sub-stations in the high-rise buildings serving also adjacent low-rise buildings to the north. Heat is supplied via district heating.

2.1 Buildings

All buildings have concrete element walls, 2-pane windows, flat roofs, one-pipe (water) radiator systems for heating and supply and exhaust air systems for ventilation. Figures 2 and 3 show the buildings. The buildings comprise flats with 1, 2, 3 and 4 rooms plus kitchen with an average floor area of 75 m²,

2.2 Energy usage

Introductory investigations showed an average annual heat supply of the order of 5 000 MWh or 270 kWh per m² heated floor area.

Rather poorly insulated walls and windows, together with high ventilation flow rates (and poorly insulated supply air ducts in the low-rise buildings) explain the rather high heat energy usage.

The annual use of electricity amounted to about 1 000 MWh or 53 kWh per m² heated floor area and the annual use of water amounted to about 44 000 m³ or 3.36 m³ per m² heated floor area with 30% non-occupied flats. The cost for electricity and water was included in the rent as there were no individual meters in the flats.

Fig. 2 View from one high-rise building over the yard to northeast. Left: Roof tops with ventilation systems on a low-rise building. Right: High-rise building with balconies facing south.

Fig. 3 View from one high-rise building over the yard to northwest (clockwise Fig 2). Left: High-rise buildings with balconies facing south. Right: One low-rise building.

3. Applied measures

The solar renovation is to a large extent based on experiences from the work within IEA SH&CP, Task 20 (Boonstra et al, 1998). Design and monitoring is documented by Dalenbäck (1999). The applied measures in Gårdsten are described more in detail by Dalenbäck and Nordström (2001).

3.1 High-rise buildings

Major solar renovation measures are applied to the high-rise buildings facing south. The flat roof is rebuilt to a new inclined roof with integrated solar collectors for pre-heating domestic hot water. Furthermore the supply air system (here placed in the basement) is removed and replaced by air inlets via glazed south-facing balconies. See Figures 4 and 5.

Bedrooms and living rooms are situated on the south side that makes it possible to take outside air via the balconies and use the existing exhaust from bathrooms and kitchen on the north side.

The exhaust ventilation is operated with a minimum flow dependent on outdoor temperature and the kitchens are equipped with separate kitchen fans with carbon filters. The new outside air inlets are designed as "brush sealings" in windows and balcony doors.

The applied glazing on the balconies, from Pingvin, comprises single glass without frames that are 100% openable and easy to clean (can be folded to one side of the balcony). See Fig. 6.

In order to improve architectural and social conditions, making the building area more attractive, new washing rooms and large greenhouses are built on the ground floors of the high-rise buildings.

The greenhouses are located in direct connection with the washing rooms and organised that all tenants have a piece to grow tomatoes or similar.

Washing machines, as well as dryers, are connected to the DHW system in order to utilise solar and district heat instead of electricity at water temperatures below 50°C.
The solar DHW systems are designed with about 3 m² of collectors per flat and connected to buffer storage tanks in the basement.

The solar collectors are designed as roof modules, i.e. they are both a roof and a collector mounted directly on the roof trusses. The roof modules are manufactured by Derome AB.

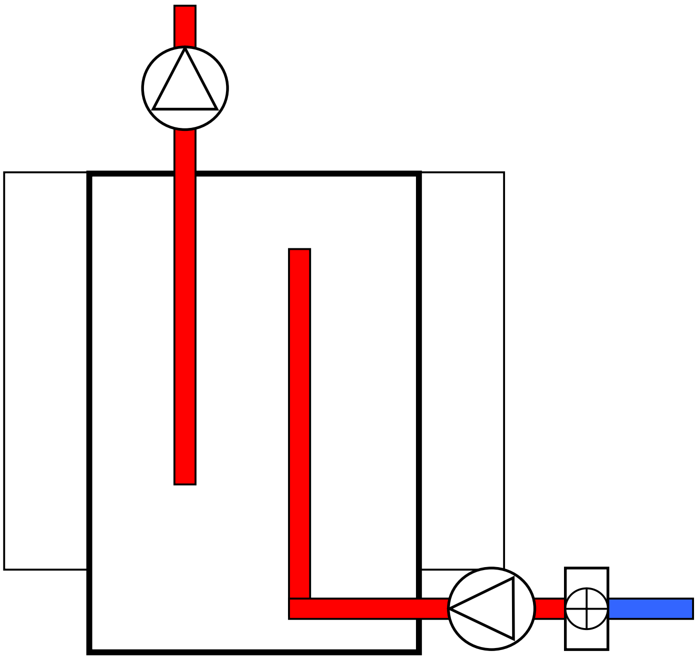

Fig. 4 High-rise building with supply and exhaust ventilation before renovation.

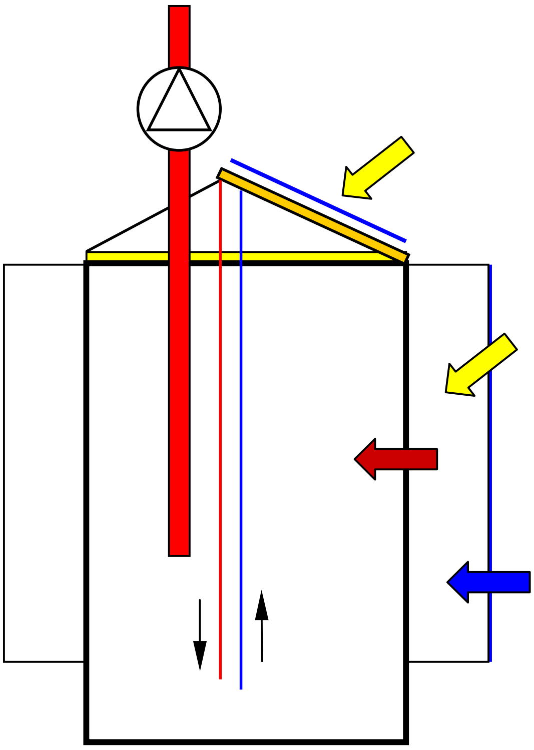

Fig. 5 High-rise building with new roof, roof-integrated collectors, glazed balconies and exhaust ventilation after renovation.

Fig. 6 South facing façade with glazed balconies and greenhouse. Photo: C. Nordström.

Fig. 7 High-rise building with roof-integrated collectors and glazed balconies under construction.

3.2 Low-rise buildings

The low-rise buildings are equipped with solar heated DHW (from the high-rise building) and heat recovery on ventilation, having both supply and exhaust fans on the roof according to figures 8 and 9.

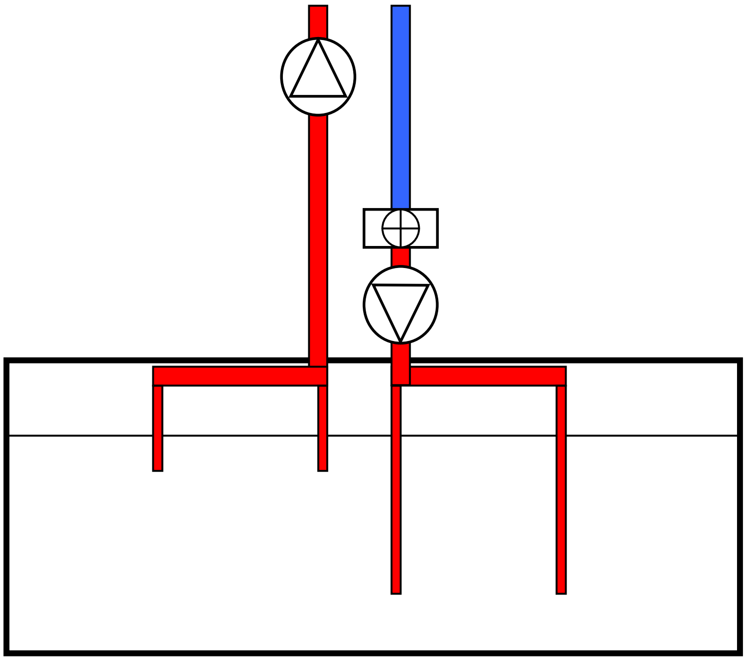

Fig. 8 Low-rise building with supply and exhaust ventilation before renovation.

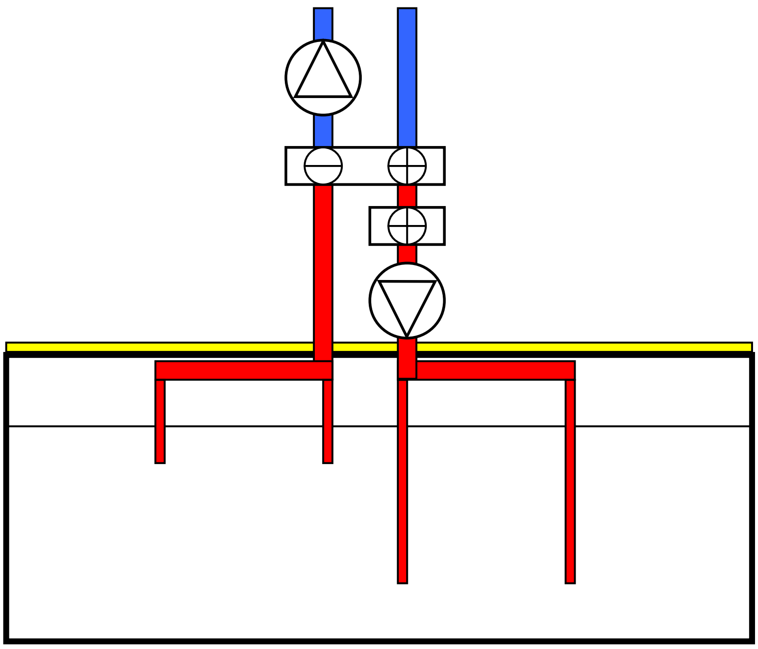

Fig. 9 Low-rise building with heat recovery and new roof cover after renovation.

A new roof cover with additional insulation improves the thermal insulation of the existing air supply ducts as the ducts are situated close to the roof cover.

The edges of the floor slabs have also been insulated in order to improve the thermal comfort on the ground floor.

Initially it was planned to put new inclined roofs also on the low-rise buildings. However, the final decision was to put additional insulation and a new cover on the existing flat roofs, mainly due to favourable investment costs. See Fig. 10.

Fig. 10 Low-rise building with new roof covers and enlarged roof tops for the new ventilation systems.

Furthermore, one low-rise building facing south is equipped with solar air collectors facing south and a new double envelope wall on facades facing east, west and north.

3.3 Common features

In general additional insulation was hard to motivate due to low heat costs (district heat mainly generated from misc. waste energy). However, windows that were in a bad shape are replaced by new improved windows and the inside pane in remaining windows is replaced by a new low-e pane. Furthermore, the gables on the high-rise buildings have got a new cladding and additional insulation due to problems with water penetration (high wind loads).

All systems are connected to a central PC-based control system for supervision and data logging. All flats have got a major face-lift together with new low energy stoves, refrigerators, etc. low flow water taps and toilettes and occupancy censors control lamps in staircases.

There was furthermore an ambition to save energy by creating opportunities for the tenants to influence their energy bills. Therefore, individual meters for electricity, water and space heating are installed in all flats.

The individual space heating requirements are determined by monitoring the average temperature, i.e. the thermal comfort, in each flat. An average temperature of 21 °C is seen as default and temperatures above or below will influence the cost for the tenants.

3.4 Summary of measures

The participation in the SHINE project allowed time for the development of a comprehensive proposal for measures. In most cases, the proposals were based on a comparison of a basic alternative, which consisted primarily of essential maintenance, and a more expensive alternative (although constrained by a more or less given budget for additional investments) that would result in energy savings. Finally, the Solar House project consisted of a carefully thought-out renovation plan, in which most of the additional costs for energy conservation measures were offset by reduced running costs. The energy-related measures, out of which one is roof-integrated solar collectors, can be summarised as follows:

- Conversion of balanced ventilation systems to exhaust ventilation systems or balanced systems with heat exchange in connection with the obligatory ventilation control (OVK).
- Glazing of balconies in connection with their renovation (damaged concrete elements).
- Replacement of inner window panes by low-emission panes in existing double-glazed windows.
- Roof-integrated solar collectors as part of the outer roof renovation.
- Additional roof insulation as part of the outer roof renovation.
- Additional insulation of end walls as part of the facade renovation.
- Insulation of footings in connection with improving foundation drainage systems.
- New washing machines and drying room equipment, connected to the hot water supply.
- New energy-efficient appliances as part of internal apartment renovations.
- Replacement / upgrading of fittings as part of bathroom renovations.
- Installation of presence-controlled lighting in common areas.
- Installation of a central control and supervisory system.
- Installation of individual metering of electricity, heating and water.

Fig. 11 Overview of all three blocks. The most northern block is finished, the second block is partly ready and the renovation has just started in the third block (closest). Photo: C. Nordström

4. Evaluation results

4.1 Supply of district heat

The projected result was that proposed renovation measures were expected to reduce the annual heat supply, i.e. district heat, from 5 000 to 3 000 MWh (i.e. from 270 to 160 kWh/a.m² heated floor area).

Measurements according to Table 1 show that the actual annual heat supply is reduced to below 2 800 MWh (or 150 kWh/.m² heated floor area) in 2004.

Table 1. Normalized district heat supply

Year	[MWh]	[kWh/m²]
Before	5 000	270
2001	3 466	185
2002	3 228	172
2003	2 804	150
2004	2 725	146

The actual measured heat supply is here normalized to an average year using degree-days. The actual savings of district heat supply amounts to more than 40%. Major energy savings have occurred for ventilation (heat recovery, pre-heating of ventilation air in glazed balconies), radiators (additional insulation, replaced windows) and domestic hot water (solar collectors for pre-heating).

4.2 Solar DHW system

The solar DHW system comprises 705 m² of solar collectors on three high-rise building (~3 m²/flat). The solar systems were expected to gain about 300 MWh per year an average year.

Table 2. Measured solar heat supply

Year	[MWh]	[kWh/m²]
Design	300	~400
2001	309	438
2002	299	425
2003	295	442
2004	311	476

Table 2 shows the actual measured solar heat supply from 2001 to 2004 amounting to about 450 kWh/a.m² collector area. This amount relates to reduced district heat supply of the order of 15 kWh/a.m² heated floor area.

4.3 Supply of electricity

The total annual use of electricity before renovation amounted to about 1 000 MWh (~4 000 kWh/flat) or 55 kWh/m² including common and household electricity use.

Table 3. Measured total use of electricity

Year	[MWh]	[kWh/m²]
Before	1 030	55
2001	964	52
2002	986	53
2003	992	53
2004	998	53

The measured total annual use of electricity from 2001 to 2004 is more or less the same as before renovation (Table 3). Here it should be noted that about 30% of the flats were non-occupied before renovation, which means that the specific savings of the order of 30% have occurred in practice.

It could further be noted that the use of electricity is more or less the same for all four years, i.e. there are only initial savings related to renovation measures and new occupants.

4.4 Water usage

The total annual use of water before renovation amounted to about 44 200 m³ (173 m³/flat). The actual measured total use of water is reduced by about 30% to about 30 000 m³ (120 m³/flat) in 2004 (Table 4). Here it should also be noted that about 30% of the flats were non-occupied before renovation, which means that the specific savings are larger.

Table 4. Measured total use of water

Year	[m³]	[m³/flat]
Before	44 200	173
2001	31 308	123
2002	31 307	123
2003	31 190	122
2004	30 514	120

It could further be noted that the use of water is more or less the same for all four years, i.e. there are mainly initial savings related to renovation measures and new occupants.

5. Individual metering

All flats are equipped with a system for individual metering of household electricity, cold and hot water usage, as well as space heating requirements. The metering system comprises one unit per flat, a number of collecting units with a modem placed in the staircases and a central PC where collected data are collected and stored every two weeks.

Metering of household electricity is based on rather simple electricity meters and metering of water usage is based on simple wing-wheel meters with pulse outputs. The space heating requirements are determined based on room temperature measured with sensors in living rooms and bedrooms taking averages every second hour.

The individual metering system was put in operation in 2000 and the tenants association approved to use the system for individual bills in 2001. The individual billing is based on a fixed cost included in the rent and additional cost related to the actual electricity and water usage as well as room temperature.

The result of the individual metering from 2001 to 2004 is summarized in the following. The diagrams show the average for the whole block including 255 flats in 10 buildings, as well as the variation between buildings. The result from the individual metering is elaborated more in detail by Pavlovas (2006).

5.1 Household electricity

The individual metering system makes it possible to relate the use of household electricity to the total use of electricity, i.e. including common use of electricity for ventilation fans, laundries, outside and staircase lighting, etc. Table 5 shows the specific use of electricity.

Table 5. Measured use of electricity [kWh/a.m²]

Year	Household	Total
2001	28	52
2002	(27)	53
2003	31	53
2004	33	53

Table 5 shows a small increase in the use of household electricity although the total use of electricity as previously mentioned has been more or less the same during the evaluation period.

In order to get an overview of the development, the average monthly use of household electricity is presented in Fig. 12. The figure shows that the average household electricity use varies between 150 and 250 kWh/month and flat, i.e. about 1 800 to 3 600 kWh/year and flat.

It can be observed that there is a rather significant variation related to outside temperature which indicates that electricity may be used for heating in some apartments.

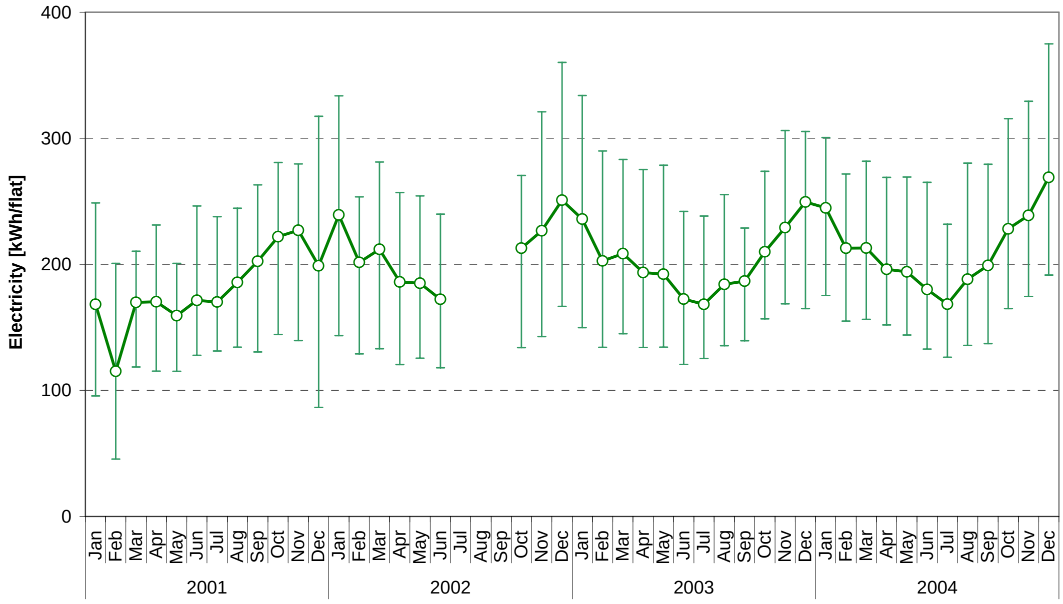

Fig. 12 Household electricity from January 2001 to December 2004. Monthly average for 255 flats in 10 buildings indicating the min/max for building averages.

5.2 Household water usage

The individual metering system makes it possible to relate the individual use of water to the total use of water, i.e. including common use of water for laundries, etc. Table 6 shows the specific use of water.

Table 6. Measured total use of water [m³/a.flat]

Year	Household	Total
2001	107	123
2002	(99)	123
2003	104	122
2004	102	120

Table 6 shows a small decrease in the use of individual water although the total use of water as previously mentioned has been more or less the same during the evaluation period.

In order to get an overview of the development, the average monthly individual use of cold and hot water is presented in Fig. 13 and 14. The figures show that the average cold water use varies between 4 and 7 m³/month and flat while the average hot water use varies between 3 and 5.5 m³/month and flat, i.e. the hot water use amounts to about 40% of the total use of water.

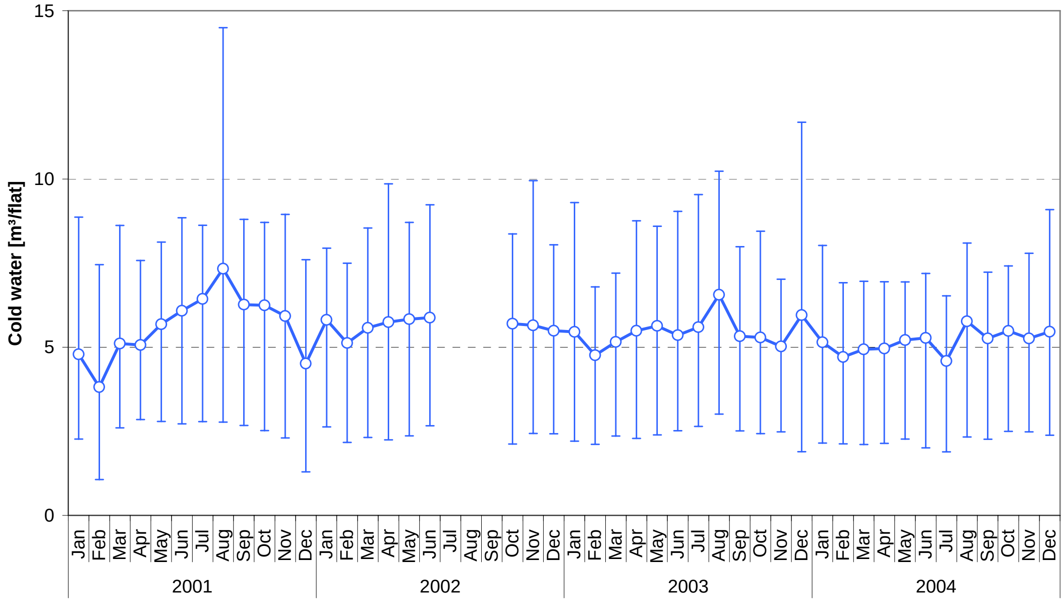

Fig. 13 Cold water use from January 2001 to December 2004. Monthly average for 255 flats in 10 buildings indicating the min/max for building averages.

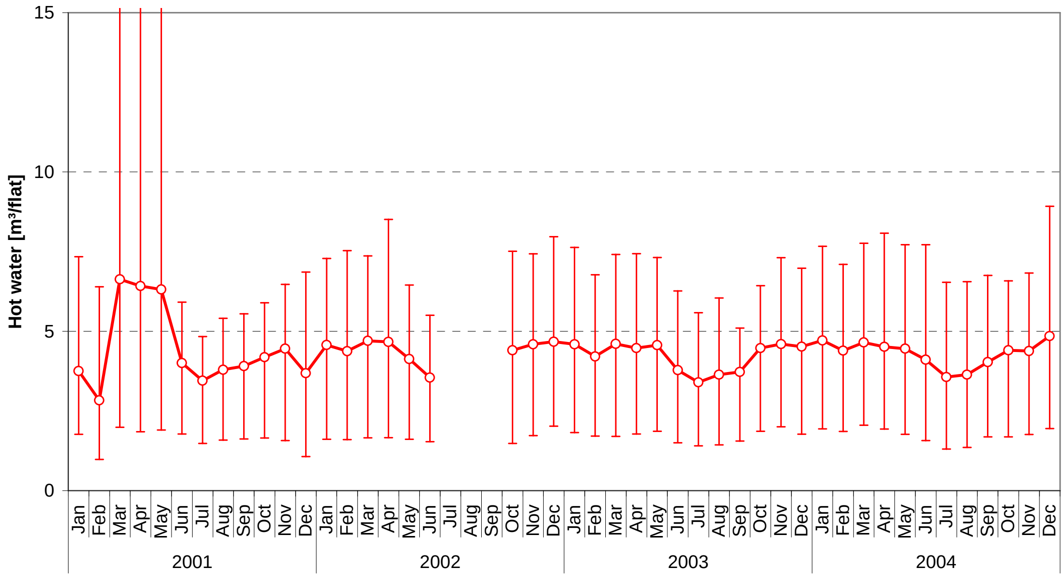

Fig. 14 Hot water use from January 2001 to December 2004. Monthly average for 255 flats in 10 buildings indicating the min/max for building averages.

5.3 Room temperature

The room temperature is used to represent the amount of heating energy used by the tenants. The base case is that the tenants should have 21°C. If they want to increase the temperature they have to pay extra and if they want to save money (and energy) they can lower the temperature. The prerequisite to allow for this is the use of individual and adjustable room thermostats.

In order to get an overview of the development, the average room temperature is presented in Fig. 15. From initially rather high and different room temperatures during the heating season 2000/2001 the average room temperature has gradually been lowered by balancing the heating system and adjusting the supply temperature.

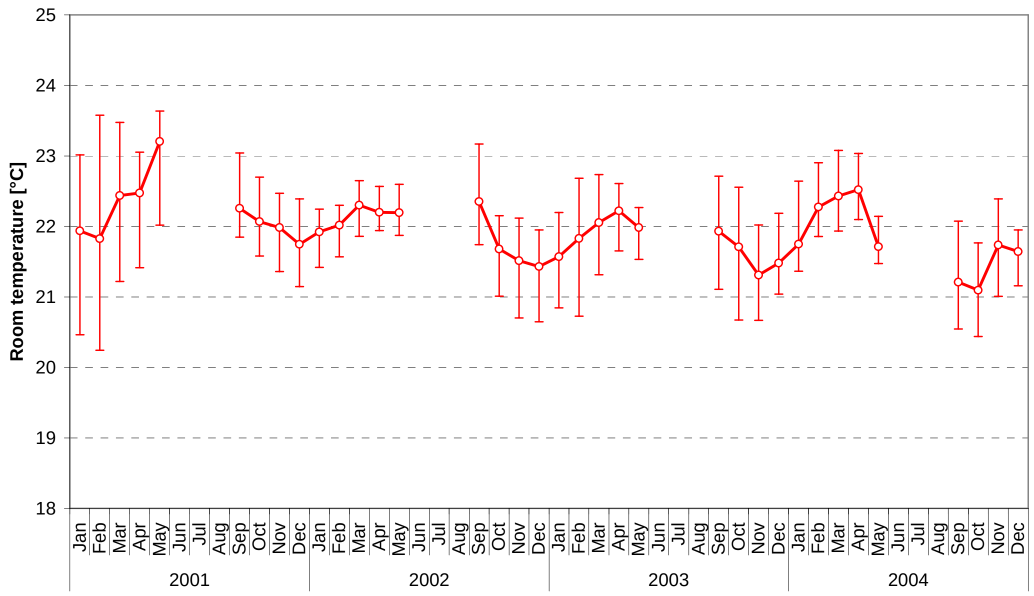

Fig. 15 Average room temperature from January 2001 to December 2004. Monthly average for 255 flats in 10 buildings indicating the min/max for building averages.

It could be noted that there is a variation in the average room temperature around 21°C that will be analysed more in detail in a separate article.

5.4 Individual costs

A major feature of the individual metering systems is that the tenants are to pay based on their individual use. The individual costs are related to the individual deviation from 21°C average room temperature, 120 m³ water and 2 400 kWh electricity per flat and year. The influence of the individual billing is presented more in detail by Pavlovas (2006).

6. Conclusions

The Gårdsten project has gained large interest from journalists and other housing companies with similar areas and the tenants are satisfied with their new environment.

This demonstration project combines traditional energy savings measures and solar applications in an interesting cost perspective. This had not been possible without the genuine interest from the building owner to adopt new ideas. Here, the possibility to receive financial support from EC has been an important encouragement. However, the major driving force was the common interest to improve the building area and state an example for future renovations.

Furthermore, the use of experienced consultants and rather detailed analyses regarding possible energy savings and combination effects are other pre-requisites in order to get an acceptable result.

Every project has its own pre-requisites. However, taking the above into mind, there are great possibilities to apply similar measures at reduced costs in other similar building areas.

All measures have in principle met or exceeded the expectations, the projected costs are kept and the evaluation results are in good agreement with the expectations regarding energy savings. As a result the housing association decided to carry out a similar renovation of another three blocks. The so called “Solhus 2” project was finalized late 2003. The aim here was to apply similar measures with improved tendering, project management and project commissioning in order to get even better results and decreased investment costs.

A more detailed analysis of the influence of individual metering on energy savings, as well as the main experiences from the Solhus 2 project, is presented by Pavlovas (2006).

Key indicators

Key indicators for the Solar House 1 project (1 Euro ~ 9 SEK).

	< 2001	2004	
No. of buildings	10	10	
No. of apartments	255	255	
Residential area	18 720	18 720	m^2
Occupancy	~ 65	~ 100	%
Total cost (including VAT and developer's costs)	105 5 615		SEK million SEK/m^2
Part costs for energy-related measures	~ 20 ~ 1 070		SEK million SEK/m^2
Contract guarantee	5		Year
Operating costs	~ 3,94 210	~ 2,70 144	SEK mill./year SEK/year,m^2
District heating	~ 5 000 ~ 270	~ 2 725 ~ 146	MWh/year kWh/year, m^2
Solar heat for DHW		~ 336 ~ 18	MWh/year kWh/year, m^2
Electricity use (NB; changed occupancy)	~ 1 030 ~ 55	~ 1 000 ~ 53	MWh/year kWh/m^2, year
Water use (NB; changed occupancy)	~ 44 200 ~ 2,36	~ 30 500 ~ 1,63	m^3/year m^3/m^2, year

The area definition used is the apartment area or the rented area, i.e. excluding staircases, etc – in Swedish “Bostadsarea”, or short “BOA”.

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