Abstract - A residential building area in Gårdsten, Göteborg, is being renovated as part of an EU THERMIE. The aim is to demonstrate a comprehensive integrated renovation concept, comprising energy conservation 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 the SHINE project covers 172 out of 255 flats in three blocks. One innovative solar feature is prefabricated roof modules with integrated water collectors; another is an air collector combined with a double envelope wall. The construction started in 1999 and the paper describes applied measures, estimated costs and preliminary results.

1. INTRODUCTION

In 1993 a new task "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 about solar collectors, glazed balconies and transparent insulation published by James & James (Boonstra et al, 1998).

This paper 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 is now realised together with 5 similar projects with financial support from EC (SHINE, project no 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. The Gårdsten area has a high rate of immigrants, the buildings lack 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 were developed late 1998. The construction started early 1999, the first block was commissioned early 2000 and the whole project will be finalised in 2001.

2. EXISTING SITUATION

The Gårdsten area is divided in two parts, East and West Gårdsten. Both parts comprises 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. Figure 1 shows a site plan. 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.

Fig. 1 Site plan showing three blocks where the present demonstration project takes place.
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.

![Fig. 2 View from one high-rise building over the yard to northwest. Left: High-rise buildings with balconies facing south. Right: One low-rise building.](image1)

![Fig. 3 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.](image2)

2.2 Energy usage
Introductory investigations showed an average heat supply of the order of 5 000 MWh/a or 270 kWh/a and 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 use of electricity amounts to about 50 kWh/a and m² heated floor area. The electricity cost is included in the rent as there are no individual meters in the flats.

2. 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).

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 preheating 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 Figure 4 and 5.

![Fig. 4 High-rise building with supply and exhaust ventilation before renovation.](image3)

![Fig. 5 High-rise building with new roof, roof-integrated collectors, glazed balconies and exhaust ventilation after renovation.](image4)
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 solar 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.

The applied glazing system was mounted using a huge lift that moved up and down the facade for easy mounting on the balconies. The glazing, from Pingvin, comprises single glass without frames that are 100% openable and easy to clean (can be folded to one side of the balcony).

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. Figure 10 shows the interior of the greenhouse.

![Greenhouse interior](image)

**Fig. 10** Greenhouse interior. Photo: C. Nordström.

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.

### 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 11 and 12.

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.

![Low-rise building with supply and exhaust ventilation](image)

**Fig. 11** Low-rise building with supply and exhaust ventilation before renovation.

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

![Low-rise building with heat recovery and new roof cover after renovation](image)

**Fig. 12** Low-rise building with heat recovery and new roof cover after renovation.

Furthermore, one low-rise building facing south is equipped with solar air collectors facing south and a double envelope wall on facades facing east, west and north. The solar heated air is circulated in an air gap between a new insulated envelope and the old facade. See Figure 14.

The overall design is based on a previous similar project equipped with air-to-water heat exchangers for pre-heating DHW during the summer period. Here, solar pre-heating of DHW is managed already and the system is designed with vertical façade collectors for heating only. See figure 14 and 15.

![Low-rise building with new roof covers and enlarged roof tops for the new ventilation systems](image)

**Fig. 13** Low-rise building with new roof covers and enlarged roof tops for the new ventilation systems.
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 will get a major face-lift together with new low energy stoves, refrigerators, etc. and occupancy censors control lamps in staircases. All facades and windows are painted in new light colours.

Furthermore, there is an ambition to save energy by creating opportunities for the tenants to influence their energy bills. Therefore, individual meters for electricity, hot 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 (<23 °C) or below (>18 °C) will influence the cost for the tenants.

4. EXPECTED RESULT

The projected result is that proposed renovation measures are expected to reduce the annual heat supply from 5 000 to 3000 MWh (i.e. from 270 to 160 kWh/a.m² heated floor area) according to figure 17.
Major energy savings will occur for ventilation (heat recovery, pre-heating of ventilation air in glazed balconies), radiators (additional insulation, replaced windows, solar heated house) and domestic hot water (solar collectors for pre-heating).

Preliminary monitoring results from the first block during March and April 2000 shows expected energy savings regarding heating and ventilation. This first block will be evaluated more in detail and a final report is expected early 2000.

The renovation measures are also expected to result in reduced electricity usage. However, here an important aspect is that only about 70% of the flats are occupied at present. Therefore, although the use of electricity per person will be reduced the total usage of electricity will remain about the same with all flats occupied.

5. RENOVATION COST

5.1 Investment cost

The SHINE project is part of a comprehensive renewal of in total 1000 flats. The first phase comprises 255 flats, where 172 belong to the SHINE project. A major consideration regarding the first cost estimates was the boards concern for the overall project (1000 flats). After several investigations and cost estimates the board could accept total cost in the first phase as shown in Table 1.

The approved total cost amounts to 98.7 MSKR (~11.5 MEUR, 255 flats), where the eligible cost, mainly solar renovation, amounts to 13.5 MSKR (~1.6 MEUR, 172 flats). This means that the average renovation cost amounts to 390 kSKR (~45 kEUR) per flat, where the cost for "solar renovation" in 172 flats amounts to 78 kSKR (~9.1 kEUR) per flat.

The dominating cost, about 30 MSKR (~3.5 MEUR) or 117 kSKR (~13.7 kEUR) per flat, is related to neglected maintenance in flats. Given cost estimates show total costs, i.e. anticipated contract costs multiplied by 1.4 in order to include VAT (25%), authority and commissioner costs.

5.2 Cost savings

The expected annual heat savings amount to about 2 000 MWh which corresponds to annual cost savings of the order of 1 million SEK or close to 4 000 SEK per flat or slightly more than 50 SEK (~6 EUR) per m² heated floor area.

The extra cost for the "solar renovation" amounts to 78 000 SEK per apartment or about 1 000 SEK/m² heated floor area or annual capital costs of about 80 SEK (~ 9.5 EUR) per m² heated floor area (applying an annuity factor of 0.08).

The cost savings are utilised by the housing company just by keeping the annual rent, about 70 EUR/m², on the same level as before renovation. See figure 18.

The difference of 30 SEK (~ 3.5 EUR) per m² between annual cost savings and annual capital costs for renovation is compensated by the EC-support and diversified rents for different types of flats with different features, e.g. glazed balconies.

5. CONCLUSIONS

The Gårdsten project has gained large interest from journalists and other housing companies with similar areas and the tenants are so far 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. 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.
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