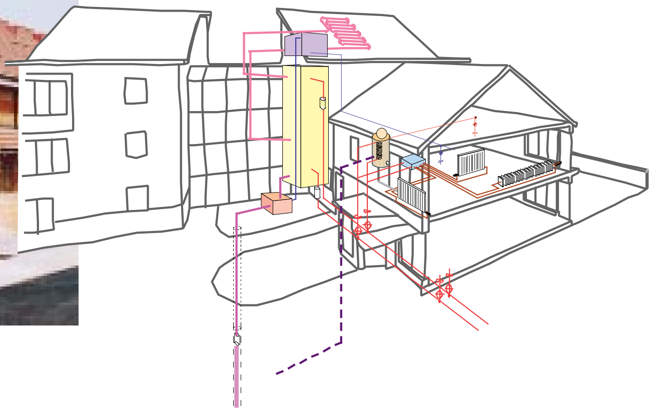
Energy-efficient housing association schemes

- SAP energy ratings of between 94 and 100
- Fabric insulation values well above typical current standards
- Homes built at little additional cost



ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE CASE STUDY 378

CONTENTS

1 INTRODUCTION

Energy use in housing is a major contributor to the UK's total energy consumption and carbon dioxide (CO_2) emissions. Emissions of CO_2 from housing in 1996 were between 140 and 150 million tonnes. Housing associations are responsible for a significant proportion of new housing and refurbishment every year, and this presents opportunities to reduce energy use and associated emissions.

The Housing Corporation has established energy efficiency standards in its 'Scheme Development Standards'[1], in terms of minimum and recommended Standard Assessment Procedure (SAP) energy ratings. Tai Cymru has also established minimum requirements. These ensure that new housing association dwellings meet higher standards of energy efficiency than required by current Building Regulations. However, a number of projects around the UK demonstrate that further improvements in energy efficiency can be achieved by housing associations, at little additional cost compared with typical scheme development costs.

ABOUT THIS CASE STUDY

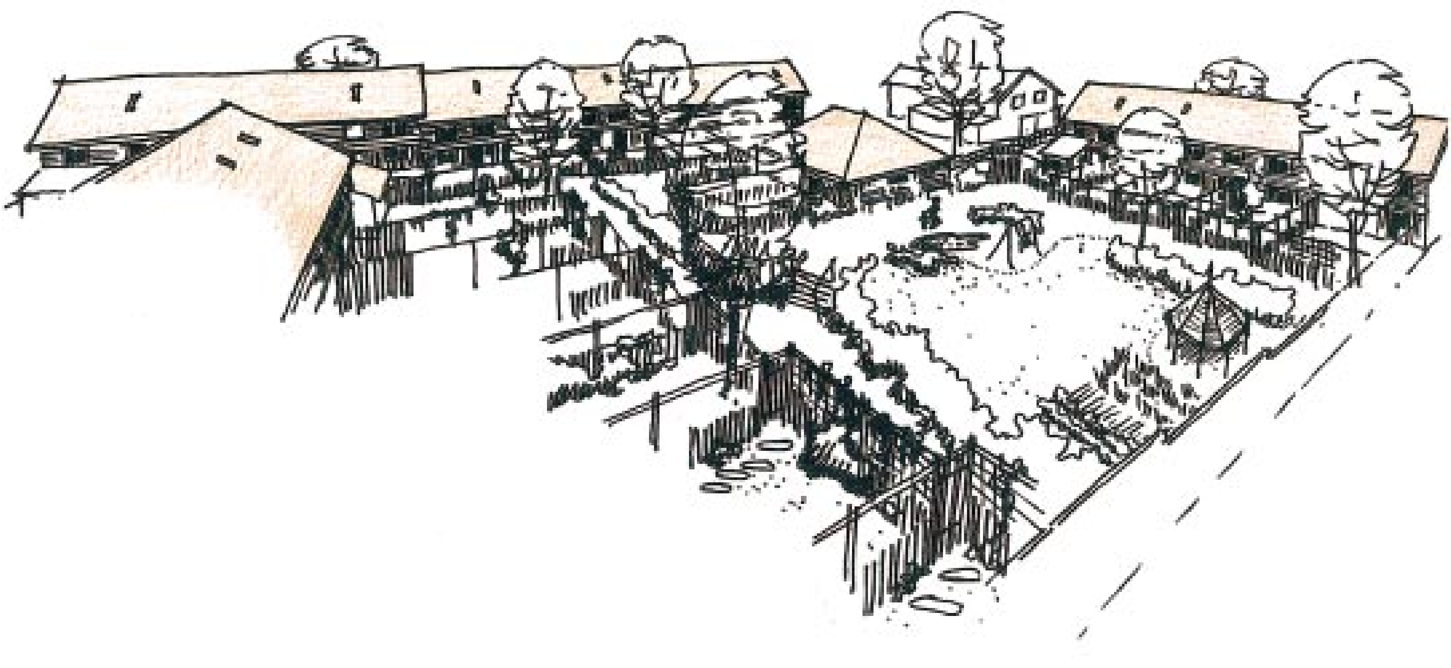
This Case Study is written primarily for housing and planning managers within local authorities and housing associations, and may also be of interest to architects and consultants. The Case Study describes four new housing association schemes that illustrate the possibilities for improved energy efficiency standards. They show how a variety of technologies and approaches to the procurement process can lead to improved energy efficiency while, at the same time, keeping cost low. None of the schemes have received any special or additional funding for inclusion of their energy efficiency measures. A number of other environmental issues have also been addressed.

Summary details of the four schemes are presented overleaf, and a discussion of their approach to a variety of issues follows. The construction specifications are shown in table 5 on page 12, and references and further reading are listed on page 14.

This Case Study is produced as part of the Energy Efficiency Best Practice programme, managed by BRECSU on behalf of the Department of the Environment, Transport and the Regions (DETR).

CO_2 emissions in this Case Study are quoted as kg of CO_2/m^2. Conversion from CO_2 to carbon is the ratio of their respective atomic weights (44:12). Thus, 100 $kgCO_2/m^2$ expressed as carbon is:

$$\frac{100 \times 12}{44} = 27.3 \text{ kgC/m}^2$$



2 THE SCHEMES

The Harlow Park scheme comprises 23 houses constructed with consideration given to the use of sustainable materials

1 HARLOW PARK, LIVERPOOL

CDS Housing Association wished to improve the environmental performance of its housing. The architect's brief for this scheme was to develop a 'greener' specification and construct a pilot project. The specification was to minimise the use of building materials with high embodied energy, with the emphasis on using sustainable materials.

Summary points

- The brief was to produce a scheme for a standard development budget plus 2.5%.
- The site previously consisted of four-storey blocks of council maisonettes, built in the 1950s, which were in poor condition and due to be demolished.
- The scheme includes 23 new houses arranged around a courtyard and built using highly insulated 'I-beam' timber frame construction with brick, render and timber-boarding wall finishes.
- As a result of this project, CDS is planning to improve the performance of other schemes, including a minimum SAP energy rating of 90. Further changes will depend on the perceived success of this project with tenants.

Co-operative Development Services (CDS) Housing Association

Architect:	Architype Architects
Typical house floor area:	84 m^2
Completed:	July 1998
Construction cost:	approximately £1 124 000

The Heather Close development comprises five houses with a compact two-storey layout

2 HEATHER CLOSE, HAMPTON, LONDON

The London Borough of Richmond ran a competition for housing associations to put forward energy-efficient designs. The aim of the L&Q scheme was to achieve a high SAP energy rating together with a reduction in CO_2 emissions.

Summary points

- L&Q has built several exemplar energy-efficient housing schemes, and, together with PRP Architects, submitted the winning entry.
- The competition site was a small infill plot in a residential area close to a railway line.
- The scheme consists of a terrace of five houses with a compact two-storey layout intended to maximise passive solar gains.
- The main living rooms face south and have increased window sizes. Service spaces are kept to the north side.
- The houses are built using traditional masonry construction with wide, fully insulated cavities, and with gas-fired central heating systems incorporating condensing boilers.

London and Quadrant (L&Q) Housing Trust

Architect:	PRP Architects
Typical house floor area:	75 m^2 and 87 m^2
Completed:	July 1997
Construction cost:	approximately £256 275

THE SCHEMES

3 MOUNT PLEASANT, WEMBLEY

A review of the energy efficiency standards of PCHA's existing housing stock resulted in a draft energy strategy and increased requirements for new developments. The new standards were adopted for this prototype scheme.

Summary points

- The aim was to produce highly energy-efficient dwellings to meet the needs of housing association tenants, and at a minimum cost premium to PCHA.
- The development consists of 23 units, a terrace of 11 low-energy houses and four flats, and a second terrace of 11 houses built to PCHA's normal specification.
- The dwellings are highly insulated and have low air-leakage rates, using masonry construction with very wide cavities and triple glazing.
- Heat from two electric storage heaters is distributed throughout the property using mechanical ventilation with heat recovery (MVHR) units. Hot water is supplied via a heat pump.
- PCHA will carry out a post-occupancy tenant survey, the results of which will be used to assess the occupants' perceptions about the designs.

The Mount Pleasant scheme includes a terrace of 11 all-electric low-energy houses

Paddington Churches Housing Association (PCHA)	
Architect:	Rhys Owen Architects
Typical house floor area:	95 m^2
Typical flat floor area:	49 m^2
Completed:	July 1998
Construction cost:	approximately £1 336 000

4 GLENALMOND STREET, GLASGOW

The project arose as a result of a competition run by Scottish Homes for housing associations to produce proposals for environmentally sustainable homes.

Summary points

- A primary aim was to establish what improvements could be achieved at minimum additional cost.
- SHA used this scheme as a mechanism to increase its knowledge of sustainable construction and improve its environmental specifications for new projects.
- The scheme consists of 16 units on a site in a residential area of East Glasgow, comprising a mixture of one- and two-bedroom flats and family houses.
- It uses well-insulated timber-framed 'I-beam' construction, with some prefabrication, and a variety of external wall finishes including brick, render and timber boarding. A central heating system is supplied with heat from a geothermal source with some backup from solar heating.
- The designs are intended to allow a high degree of flexibility over internal layout.
- It is a totally 'car-free' scheme, the first of its kind in Glasgow.

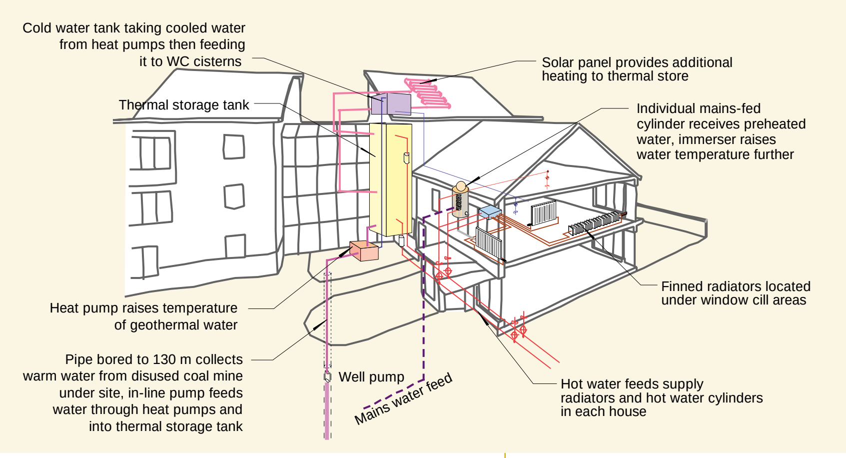


Diagram showing geothermal heating system

Shettleston Housing Association (SHA)	
Architect:	John Gilbert Architects
Typical house floor area:	99 m^2
Completion due:	May 1999
Construction cost:	approximately £748 800

3 CONSTRUCTION SYSTEMS

High levels of fabric insulation are a basic requirement for energy-efficient housing. The projects illustrate how significantly improved standards can be achieved within housing associations' cost constraints and by using a variety of construction methods. The fabric U-values for all the schemes are significantly better than those required by current Building Regulations, as illustrated in table 1.

	Exposed floors	External walls	Roofs	Windows
1995 Building Regulations (minimum elemental method)	0.45	0.45	0.25	3.30
Harlow Park	0.18	0.19	0.12	3.00
Heather Close	0.21	0.17	0.20	2.20 or 3.00
Mount Pleasant	0.13	0.17	0.20	1.30 or 1.70
Glenalmond Street	0.29	0.20	0.12	2.40

Table 1 Comparison of fabric U-values (W/m²K) of the four schemes

Traditional masonry cavity walls are used in two schemes, with increased cavity widths of 100 mm at Heather Close, and 150 mm to 200 mm at Mount Pleasant. Both schemes use proprietary insulated cavity closers, and at Mount Pleasant polypropylene wall ties are used to reduce thermal bridging. At Mount Pleasant, the builder's initial apprehension was replaced by enthusiasm once it became clear that construction of such wide cavities need not be a problem.

Timber-frame I-beam construction is used in the Harlow Park and Glenalmond Street schemes. This system of construction has the benefit of reducing the thermal-bridging effects of the structural frame while using less timber. In both schemes, blown cellulose insulation made from recycled newspapers is used between the studs.

AIRTIGHTNESS

With highly insulated building envelopes the airtightness of the fabric becomes a more significant factor in influencing the total heat loss. It is, therefore, important to reduce the leakage of air through the fabric and to provide controlled ventilation. Both at Harlow Park and Mount Pleasant, the contractors were required to meet a demanding target for airtightness of 2 air changes per hour (ach) when tested at 50 pascals (Pa) pressure difference (established using a fan pressurisation test). This is equivalent to approximately 0.1 ach at normal conditions, and is well below the 8 ach at 50 Pa average achieved in new UK housing.

To achieve such airtight construction requires attention to detail during the design and construction stages. The contractor was briefed by an energy consultant in advance of construction, thus helping to ensure that the desired air-leakage target was achieved.

At Mount Pleasant, additions to the designs included minimising the penetration through the external envelope by the use of joist hangers rather than built-in floor joists, and the ceiling vapour barrier was sealed around the edges and at service penetrations.

This was further improved at Harlow Park and Glenalmond Street to create a 25 mm service void on the inside of the external walls to avoid penetrating the walls with services.

A number of the completed houses were tested using the fan pressurisation technique to establish that the required air-leakage target had been achieved.

The provision of sufficient but controlled ventilation is of particular importance in dwellings with high levels of airtightness. The measures implemented in each of the four schemes are summarised in table 5 on page 12 of this Case Study.

CONSTRUCTION PRACTICES

The dwellings at Glenalmond Street have benefited from prefabrication, reducing site construction time and costs and improving quality. Framing systems allow the use of prefabricated panels, which are prepared in a workshop under controlled conditions and assembled on site.

A variety of external cladding finishes are available for use with framing construction systems. Many of these offer cost savings compared to traditional brick cladding, and the schemes at Harlow Park and Glenalmond Street make use of these. However, for wider-scale benefits of alternative claddings, a more flexible approach may be needed on the part of local planning authorities, which are often reluctant to accept external wall finishes other than brick.

4 SERVICES

A highly insulated and airtight envelope greatly reduces heating demand. In projects such as these, where particular attention has been paid to insulation and airtightness, the total design heat losses can be reduced to below 3 kW per hour (compared to 6-8 kW per hour for equivalent dwellings built to current Building Regulations) (see table 2). This means that, even in freezing winter conditions, the entire house can be heated by the equivalent of a three-bar electric fire. This allows significant reductions to be made in the size and capital cost of the heating systems, and enables comfort conditions to be maintained while reducing energy use.

However, for schemes to be completely successful, occupants need convincing that a central heating system is not required. For example, at Harlow Park the designers intended to install gas room heaters in the kitchen and living room and to utilise passive stack ventilation to circulate the heat. However, only one prospective tenant could be persuaded that such a system would provide comfortable conditions in all the rooms. In all other units tenants insisted on a traditional central heating system, despite the smallest available boiler being considerably larger than that required.

At Heather Close, a central heating system using a high-efficiency, gas-fired condensing boiler provides cheap hot water as well as space heating, with lower resultant CO_2 emissions. However, the boiler is oversized, principally because a condensing boiler of lower output was not available.
Due to their built form and high degree of insulation, the houses at Mount Pleasant have a low design heat loss of approximately 1 kW. For well-insulated houses, individual room heaters can provide sufficient heat to maintain comfort conditions without the need for central heating. The main issue is how to distribute the heat around the dwelling, as hot water becomes the most significant thermal load.

At Mount Pleasant, an MVHR system is used to distribute the heat from two electric storage heaters. The storage heaters are located on the ground floor – one in the living room, the other in the entrance hallway. Hot water is provided by a heat pump, using off-peak electricity, which delivers between two and three units of heat for every unit of electricity used. Although the use of electricity avoids the need for a gas connection, it increases CO_2 emissions and compared with gas is, of course, more expensive.

At Glenalmond Street, a geothermal heat source from a mineshaft below the site provides warm water at around 12ºC. This is used to supply space heating and hot water via an electric heat pump.

	Design heat loss kW	Total predicted annual fuel cost £/year	SAP energy rating
Harlow Park	2.4	498	94
Heather Close	2.5	387	96
Mount Pleasant	1.0	562	100
Glenalmond Street	3.0	535	100

Table 2 Comparison of the energy efficiency characteristics of the four schemes

5 PREDICTED ENERGY PERFORMANCE

The predicted energy performance of the four schemes is summarised in table 3. The predicted energy performances of the various schemes are not intended to be compared against each other, due to the differences in floor area, occupancy and SAP ratings. However, there are some useful observations that can be made.

Each scheme has its merits. For example, although Harlow Park has the highest overall fuel consumption, its associated CO_2 emissions are not as high as Mount Pleasant. This is because Mount Pleasant is an all-electric scheme with resultant high CO_2 emissions and higher fuel costs. Similarly, Heather Close and Glenalmond Street have similar total energy consumption and fuel costs, despite the Glenalmond Street houses being larger. This is because Glenalmond Street is able to preheat the domestic water from a geothermal source, reflected in correspondingly lower energy consumption for domestic hot water.

Although Mount Pleasant has the lowest predicted total energy use (kWh/m^2), it is the most expensive scheme in terms of total energy cost.

The schemes in this Case Study have concentrated on reducing the requirement for space heating. This has been achieved by using high levels of fabric insulation and installing energy-efficient space-heating systems. However, the housing associations have less influence on the lighting and appliances installed and used by their tenants. The BREDEM predictions in table 3 reflect this, with low space-heating and hot-water energy use and costs, but much higher total costs to include lighting, appliances, cooking and standing-charge components.

CARBON DIOXIDE EMISSIONS

The burning of fossil fuels causes CO_2 emissions. CO_2 contributes to climate change, factors of which are global warming and the greenhouse effect. Delivered electrical energy has associated CO_2 emissions of around two-and-a-half times that for the equivalent energy from fossil fuels, due to the burning of fossil fuels during the electricity-generating process at the power station.

BRE DOMESTIC ENERGY MODEL (BREDEM)

BREDEM version 12 was used to predict the running costs and CO_2 emissions of the four schemes. The assessments are based on a standard occupancy pattern of nine hours per day (sixteen at weekends) and a demand temperature in the living room of 21°C.

With low-energy designs, the predicted heating energy values, resultant fuel costs and CO_2 emissions are particularly sensitive to occupancy patterns and difficult to predict accurately.

Scheme	Space heating			Domestic hot water			Totals*			
	Energy use kWh/yr	Cost £/year	CO_2 emissions tonnes/yr	Energy use kWh/yr	Cost £/yr	CO_2 emissions tonnes/yr	Energy use kWh/yr	Energy use kWh/m^2/yr	Cost £/yr	CO_2 emissions tonnes/yr
Harlow Park 84.4 m^2 SAP 94 Five occupants	2168	36	0.5	6116	101	1.3	13 040	154.5	498	4.3
Heather Close 75.2 m^2 SAP 96 Three occupants	2808	46	0.6	3531	58	0.7	9310	123.8	387	3.2
Mount Pleasant 95.2 m^2 SAP 100 Five occupants	300	15	0.2	3697	121	2.7	8758	92	562	6.4
Glenalmond Street 100 m^2 SAP 100 Four occupants	4754	102	1.3	2724	59	0.8	9500	95	451	3.2

*The totals include predictions for energy use by lighting, cooking, domestic appliances and standing charges

Table 3 Summary of BREDEM-predicted results for the four schemes

6 PROCUREMENT PROCESS

Experience shows that, when involved early in the design stage of a development, a contractor can make a useful contribution regarding buildability and other issues affecting energy efficiency. This is demonstrated at Mount Pleasant, where the architect and housing association wanted to use the cost control and the buildability expertise of the builder. Thus, a design and build contract was used and the contractor was encouraged to suggest amendments to the specification, provided quality and performance were not affected. This has worked well, with the contractor showing increased enthusiasm for the improved specification as the project progressed.

At Harlow Park and Heather Close the architects felt that a traditional building contract administered by themselves would be the best way to control costs and quality, and to ensure that tender prices were not excessively high. In addition, at Harlow Park the design team was concerned that, for unusual or innovative construction methods, the design and build process would place too much risk on the contractor.

At Glenalmond Street the building contract was negotiated with a contractor selected by interview at an early stage in the design process. The objective was to gain the benefit of the contractor's expertise during the detailed design phase of the work. Although some of these benefits were experienced, it demonstrated the need for the designer and contractor to have a mutual understanding of the project's aims and objectives at the outset.

7 ENVIRONMENTAL ISSUES

The schemes have sought to address a range of other environmental issues. These are summarised in table 4, and include:

- reducing embodied energy
- reducing pollution emissions
- reducing waste
- providing a healthy internal environment
- controlling water use.

The most common measures include the selection of sustainable material, provision of recycling facilities for domestic waste, and specifying water-saving features.

A further focus has been to maximise the adaptability and flexibility of the dwellings to increase their useful life. For example, Harlow Park has been designed with the 'Lifetime Homes' specification in mind, developed by the Joseph Rowntree Foundation. The specification provides spaces that avoid internal structural partitions to maximise layout flexibility. The Harlow Park scheme has qualified for the BRE 'Environmental Standard' award.

	Harlow Park	Heather Close	Mount Pleasant	Glenalmond Street
Water-saving measures	Yes	No	Yes	Yes
'Lifetime Homes' specification	All	Two units	All	Some
Some sustainable materials	Yes	Yes	Yes	Yes
Some recycled materials	Yes	No	Yes	Yes
Recycling facilities for domestic waste	Yes	No	Yes	Yes
Flexible internal layout	Yes	No	No	Yes
Low-energy lighting	Yes	Yes	Yes	Yes
Tenant advice on operation	Yes	Yes	Yes	Yes

Table 4 Summary of environmental features

There are clearly difficulties with the use of recycled material and, at Glenalmond Street, this has meant that some of the original design intentions have not been met. Contractors can feel that there are difficulties in sourcing and using recycled materials. To increase the use of these materials may require allocating responsibility for sourcing suitable materials to a member of the design team.

CAR PARKING AND SITE ACCESSIBILITY

Energy use and CO_2 emissions from private cars are a significant contributor to a household's impact on the environment. The location of the site can make a significant impact on the modes of transport used. Future housing projects will need to consider what are appropriate levels of car parking provision. The Case Study schemes are all located within urban or suburban areas with public transport services. This reduces the need for car use, and may justify a reduction in the number of car parking spaces on site. However, this may meet with opposition from the local planning authority or residents.

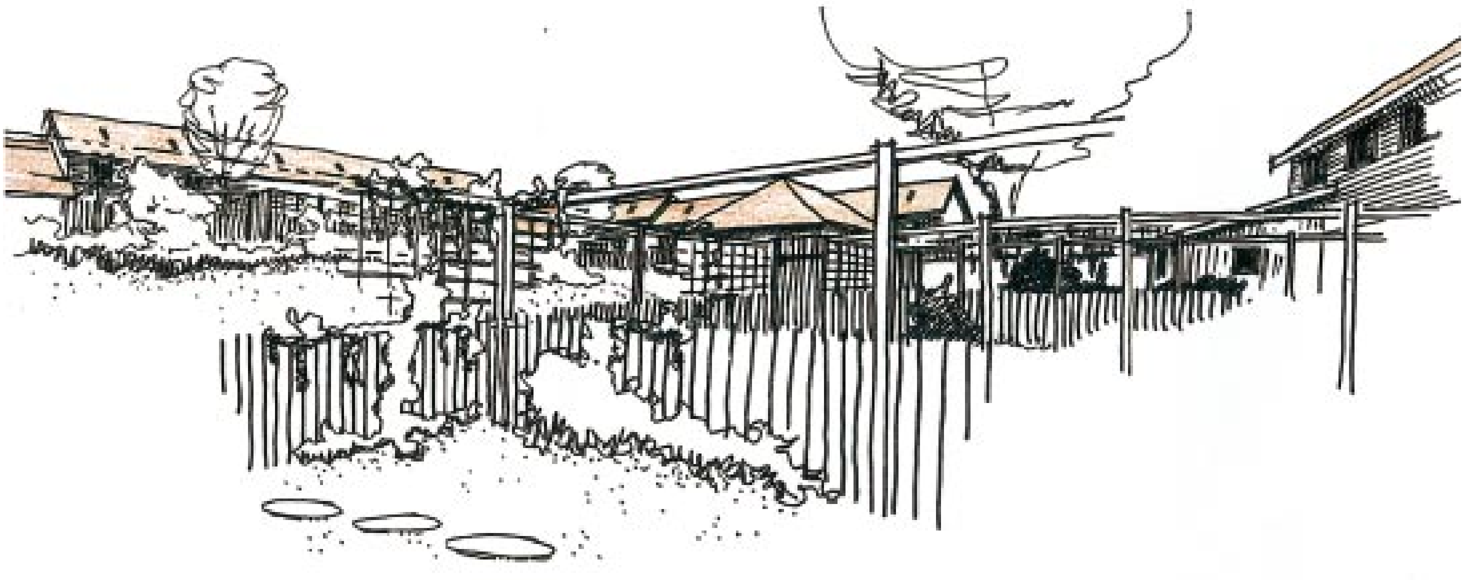
At Harlow Park a car-free communal courtyard garden area is provided, and at Heather Close the architects were able to negotiate a reduced car parking provision on the site.

This issue was addressed at Glenalmond Street where, following negotiation with the local planning authority, it was agreed to make the scheme 'car free'. The only provision is for a single car associated with the wheelchair flat, in case it was required for the tenant's mobility. The housing association requires tenants to sign a tenancy agreement that does not allow car ownership.

8 COSTS

It is wrong to think that higher standards of energy efficiency can only be achieved at significantly increased cost. These schemes all demonstrate that improved standards can have minimal cost implications. They are innovative projects that are leading the way to improved standards, and this has been achieved with very small cost premiums.

For the project at Harlow Park the architects were set a budget 2.5% above a standard development budget for such a site. At Heather Close the architects calculated that there was a 2% cost premium for the improved specification, over a base case which satisfied the Building Regulations. At Mount Pleasant the additional cost of the energy efficiency measures was accommodated within the normal margins of cost variation for such a scheme. Furthermore, PCHA is convinced that future schemes would have very little cost premium now that the builder is familiar with the technology. At Glenalmond Street the funding was from a standard allocation from Scottish Homes.



9 SPECIFICATIONS

	Harlow Park	Heather Close	Mount Pleasant	Glenalmond Street
Ground floor	Precast concrete beams with structural polystyrene blocks and a plywood finish.	Precast concrete beam and block floor with 100 mm thick polystyrene insulation and chipboard finish.	Precast concrete beams with polystyrene infill blocks covered with 40 mm thick polystyrene and a chipboard finish.	Concrete raft with 75 mm deep timber battens over and mineral wool between finished with softwood boards.
External walls	Timber frame using 170 mm deep timber I-beams, with the spaces between filled with recycled cellulose insulation, finished externally with brick, render or timber cladding, and internally with hardboard, a service void and plasterboard.	Cavity wall with 100 mm thick cavity fully filled with mineral wool, brick outer leaf and medium-density block inner leaf, plastered internally. Insulated cavity closers around all openings.	Cavity wall with 150 mm thick cavity (200 mm on end gable walls) fully filled with mineral wool, brick outer leaf and medium-density block inner leaf plastered internally. Insulated lintels and cavity closers around all openings.	Prefabricated storey-height panels constructed using 170 mm thick timber I-beams with voids filled by recycled cellulose insulation, finished externally with a sheathing board, vapour-permeable membrane and with render, larch boarding or birch.
Roof	300 mm deep timber I-beams at 1200 centres with recycled cellulose insulation between, finished externally with a breather membrane and concrete pantiles.	Prefabricated timber trussed rafters with 200 mm thick recycled cellulose fibre insulation and a concrete tile roof.	Structural insulating panels with 200 mm of expanded polystyrene (EPS) sandwiched between plywood boarding, externally finished with a vapour-permeable membrane and concrete tiles, and internally finished with a vapour barrier behind plasterboard.	Prefabricated roof structure using 300 mm thick cassettes constructed from timber I-beams and filled with recycled cellulose insulation, spanning between ridges and eaves with an external vapour-permeable membrane and concrete tiles.
Windows	Double glazing in high-performance softwood frames.	Double glazing in high-performance softwood frames; some with low-emissivity (low-e) glass.	Swedish timber frames with triple glazing using low-e glass and argon-filled cavities.	Double glazing with low-e glass in high-performance softwood frames.
Ventilation	Humidistat-controlled passive stack ventilators and humidistat-controlled wall inlets.	Humidistat-controlled passive stack ventilators and trickle ventilators in window frames.	Whole-house MVHR.	Humidistat-controlled passive stack ventilators with additional ventilation preheat in some units by taking air from beneath the roof tiles.
Heating system	Traditional gas-fired central heating with condensing boilers. One unit with gas convector heaters.	Gas-fired central heating using a condensing boiler with zone controls.	Two off-peak electric storage heaters; heat distributed by the MVHR system.	A geothermal source beneath the site serves an electric heat pump with additional heat from 4 m^2 of solar panels.
Hot water	From central heating boiler. Multi-point gas water heater for unit with gas convectors.	From central heating boiler.	An air-to-water heat pump running on off-peak electricity feeding a 150 litre storage tank with 75 mm of insulation.	From the heating system.

Table 5 Specifications for the four schemes

10 CONCLUSIONS

The experience of the housing associations in this Case Study shows that high levels of energy efficiency can be achieved at little additional cost.

A range of construction methods can be used to achieve the necessary high levels of fabric insulation and to minimise the air leakage through the fabric. In well-insulated homes, where space heating is a small proportion of energy use, hot water becomes the most significant thermal load.

All of the schemes show the feasibility of addressing environmental issues by incorporating measures such as employing sustainable materials, recycling facilities for domestic waste, and specifying water-saving features.

The wider application of the innovative techniques employed in these schemes will lower the development costs while reducing the running costs for landlords and tenants.

REFERENCES AND FURTHER INFORMATION

REFERENCES

[1] 'Scheme Development Standards'. Third edition. Housing Corporation, August 1998

DESIGN ADVICE

For a free environmental consultancy on building projects call Design Advice on 01923 664258.

FURTHER READING

BRE

- The Green Guide to Specification
- The Environmental Standard for Housing

These documents are available from CRC Ltd, 151 Rosebery Avenue, London EC1R 4QX. Tel 0171 505 6622. Fax 0171 505 6606

Association for Environment Conscious Buildings. Keith Hall and Peter Warm. 'Greener Building'. AECB, Gloucestershire, 1998

David Anik, Chiel Boonstra, John Mak. 'Handbook of sustainable building – an Environmental Preference Method for Selection of Materials for use in Construction'. James and James Publishers, London, 1996

DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given on the back cover.

General Information Leaflet

31 Building Research Establishment Domestic Energy Model (BREDEM)

General Information Reports

32 Review and development of energy efficient refurbishment standards for housing associations

46 Energy efficiency in Scottish Housing Association refurbishment projects

Good Practice Case Study

340 Environmentally sensitive housing. Dallow Road, Luton

Good Practice Guides

79 Energy efficiency in new housing (to be published by BRECSU)

82 Energy efficiency in housing – guidance for local authorities

174 Minimising thermal bridging in new dwellings. A detailed guide for architects and building designers

208 Providing energy advice to householders – a guide for local authorities and housing associations

224 Improving airtightness in existing homes

250 Energy efficiency in housing – guidance for local authorities in Wales

New Practice Final Report

22 Energy efficient refurbishment of high-rise housing. Knowsley Heights, Liverpool

Energy Efficiency Best Practice in Housing

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