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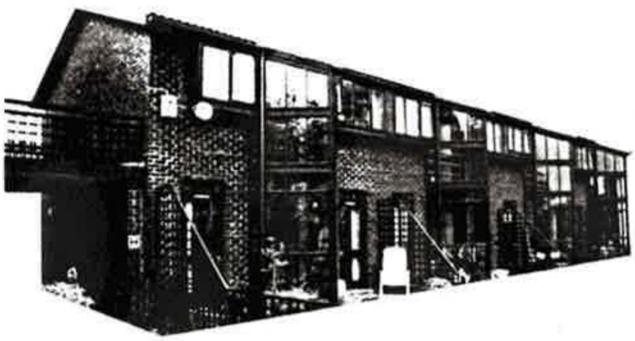
SOLAR ENERGY
A Renewable Energy

Summary Report



Spinney Gardens

ETSU S 1163/SBS/7

The work described in this report was funded by the Department of Energy and managed by the Energy Technology Support Unit (ETSU) at Harwell. The views and judgements expressed in the report are those of the contractor and do not necessarily reflect those of ETSU or the Department of Energy.

In preparing this report we acknowledge the assistance of the Building Research Establishment, who provide technical consultancy services to the Department of Energy's Passive Solar Design Programme.

"This report is one product of the Energy Performance Assessments project, a programme of field trials in a wide range of occupied buildings, covering the range of UK latitudes and climates.

The aim of the field trials is to assess the costs and benefits (energy, financial and amenity/environment) associated with incorporating passive solar principles within building design."

ENERGY PERFORMANCE ASSESSMENTS

SOLAR BUILDING STUDY

EPA SUMMARY REPORT
RESEARCH RESULTS

SPINNEY GARDENS

ENERGY PERFORMANCE ASSESSMENTS

Client :
Abbey Housing

Architect :
The PCKO Partnership

Building Type :
Private domestic

Solar Features :
Indirect Gain
Isolated Gain
Conservatory

Location :
Urban, S.E.London

Date Occupied :
1984

Size :
Gross Floor Area 64 m^2
(excluding conservatory)
Gross Floor Area 71 m^2
(including conservatory & porch)

EVALUATIONS

ENERGY	****
SOLAR DESIGN	****
AMENITY	*****
COST	****

The evaluations are based on 12 months monitoring, interviews, questionnaires, and modelling studies. For ease of comparison with other studies in this series, the performance of the building has been summarised under the four headings in the following way. Five stars indicate an excellent, three an average, and one a poor standard.

Total annual fuel use of 10896 kWh compared very favourably with that of a well insulated double glazed design. Fuel used for space heating was 80 kWh/m^2/year.

The energy performance was substantially influenced by solar gains. Without such gains gas use for space heating would have been 30% higher.

The solar performance was not at the expense of occupant comfort, for there was little reported overheating, due to the adequate isolation of the conservatory from the living areas.

Although very comfortable the building was most valued for its character, which was strongly influenced, both indoors and out, by the conservatory.

At £518/m^2 GFA (71m^2) (2nd 1/4 1989) Spinney Gardens, with a conservatory, was estimated to cost more than a comparable traditional house £506/m^2 GFA (64m^2) without a conservatory.

THE BUILDING

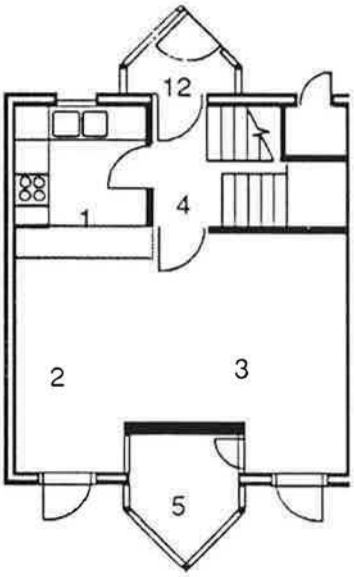
DESIGN

Spinney Gardens is located in Crystal Palace, South East London on the site of the former railway station for the nineteenth century Crystal Palace Exhibition Centre. The site comprises sixteen two bedroom houses, 20 one bedroom flats and 10 bedsitters. The houses are arranged in parallel blocks so that each house has a south/southwest orientation. The house was designed by the PCKO Partnership as an entrant in the 1981 Abbey National open architectural competition for low cost housing. Construction was carried out by the Unit Construction Company

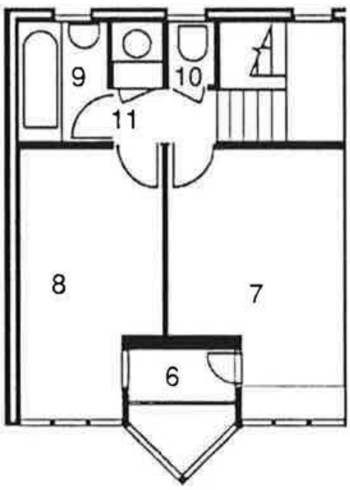
DESCRIPTION

The design, in particular the conservatories, arose in response to the site's important Crystal Palace history, the existent evidence of that history in the large arched retaining wall to one side of the site, the partnership's fundamental interest in energy efficiency, and the passive solar potential inherent in the site in the form of its orientation and sheltered position. As well as responding to the brief and the site's specific and unique characteristics the designer's other main objective was to achieve a comfortable house and one that was cheap to run.

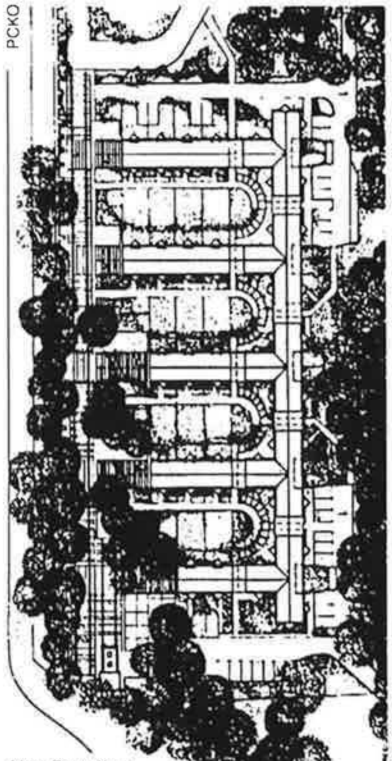
Each two storey terraced house has an open plan ground floor with two bedrooms on the first floor. A glazed 'crystal' shaped conservatory is located on the south elevation. This two storey feature is open between the floors, with a slatted floor at first floor level and can be accessed from either floor by means of a door from the adjacent bedroom or lounge. On the north elevation a single storey 'crystal' shaped conservatory, mirroring the feature on the south facade, acts as a draught lobby for the main entrance to the building. The main glazed feature, the double storey conservatory, is constructed of timber and is single glazed with 5mm float glass. The remainder of the glazing throughout the house is comprised of wood framed double glazed units



Ground floor



First floor



Site Details :

South East London	51°25'N, 0°05' W
Altitude	100m
Annual Degree-Days (20 year)	2394
Monitoring period Degree-Days	2165
Annual Sun-hours (20 year)	1353
Annual Sun-hours (Apr87-Mar88)	1446
Obstructions	E-SE Wall W-SW trees
Exposure	Sheltered, terrain (3,4)
Prevailing wind	South westerly
Mean yearly speed	3.7 m/s

Design Aids Used :

Milton Keynes Energy Cost Index

Consultants :

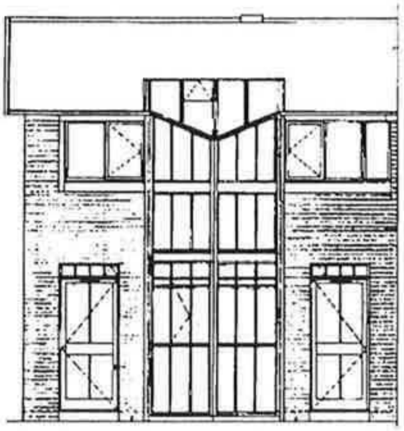
Max Fordham Services Engineer

Dates :

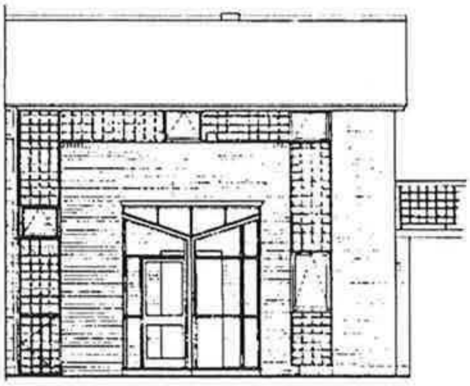
Designed	1981
Constructed	1983-1984
Occupied	1984
Monitoring period	1986-1988
Analysis period April 1987 - March 1988	

Key to space numbers :

1. Kitchen
2. Dining room
3. Lounge/Livingroom
4. Lower hall
5. Lower conservatory
6. Upper conservatory
7. Bedroom 1 (master)
8. Bedroom 2
9. Bathroom
10. Toilet
11. Landing
12. Draught lobby



South elevation



North elevation

Building Information :

Area	m²	U-value
Framed walls	34.4	0.5
Gable wall	28.8	0.6
Ground floorslab	32.4	0.6
Roof	35.1	0.3
Glazing (south)	7.4	Windows/doors
	21.4	Conservatory
Glazing (north)	1.8	Windows
	11.9	Porch
Gross floor area		64m²
(incl. conservatory & porch)		71m²
Enclosed volume		156 m³

Heating & DHW 62.5 W/m² GFA
Chaffoteaux 5kW gas fired boiler serving 5 radiators and domestic hot water needs, electric fire in the lounge. Immersion heater - not used by the occupant.

Target ventilation rate 0.9 AC/h

Heat Loss Coefficients

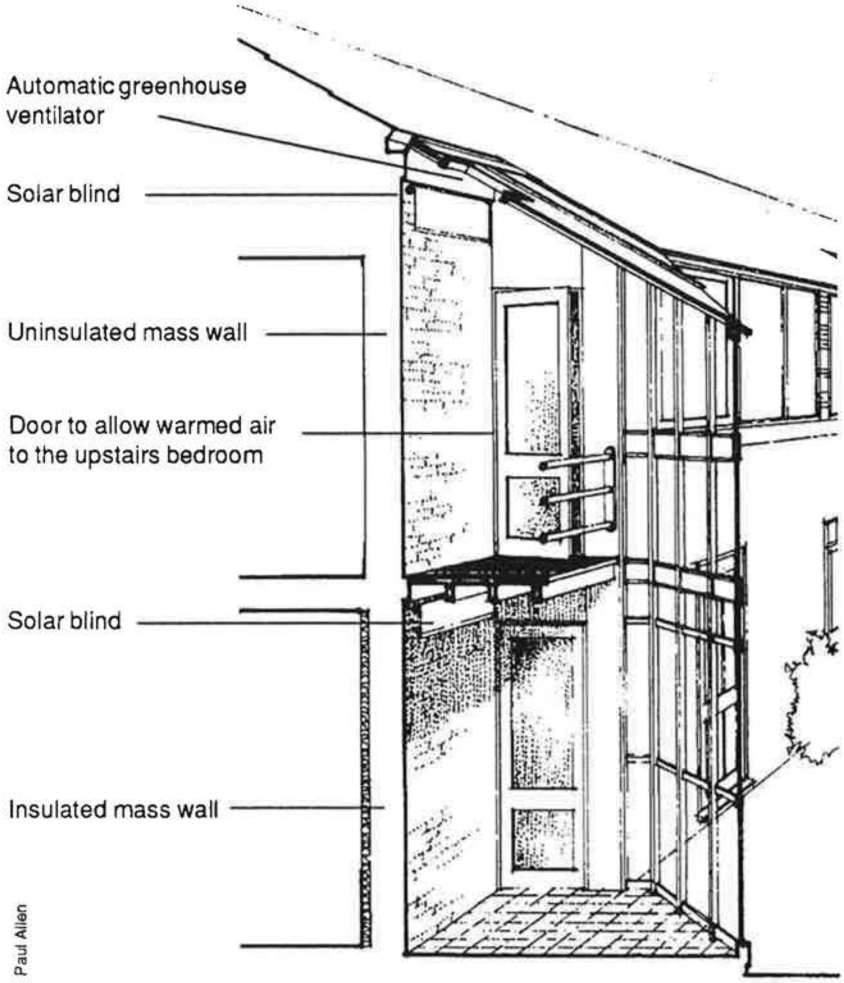
Fabric	1.6 W/°C/m² GFA
Ventilation	0.72 W/°C /m2 GFA

Design Day Heat Loss 48.7 W/m² GFA

SOLAR STRATEGY

The design is a hybrid indirect/isolated gain system which seeks to utilise solar energy to displace space heating through the circulation of warm air from a conservatory into adjacent living spaces and the transfer by conduction of heat stored in a simple accumulation wall. The main solar elements of the design are :-

a. Orientation in order to maximise the potential for solar gains.
b. Careful internal layout, with habitable spaces on the south side and service areas on the north side of the building.
c. The collection of solar energy using a conservatory on the south elevation.
d. The accumulation of heat in a thermally massive backing wall at the rear of the conservatory.
e. The control of heat transfer through the wall using solar blinds (one per floor) extending down the accumulator wall.
f. The transfer of heat stored in the accumulation wall by conduction, and, convection using established ventilation pathways, to adjacent living areas.
g. The limitation of heat losses through minimal glazing on the north elevation, a well insulated fabric and external lobbying of the north exit door.

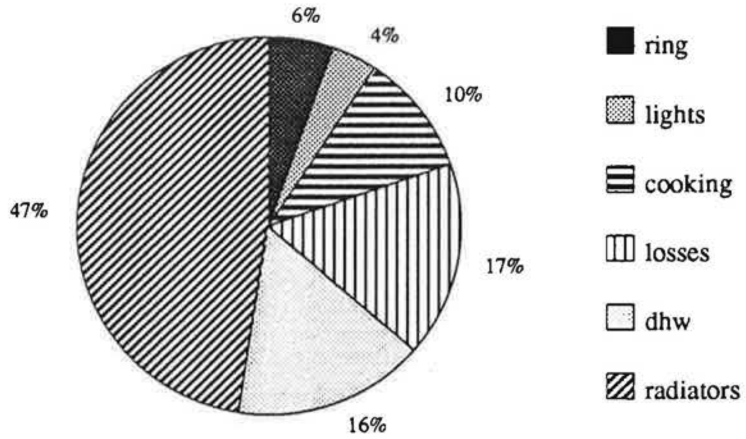


MAIN ELEMENTS IN THE PASSIVE SOLAR STRATEGY

PERFORMANCE

ENERGY AND ENVIRONMENT

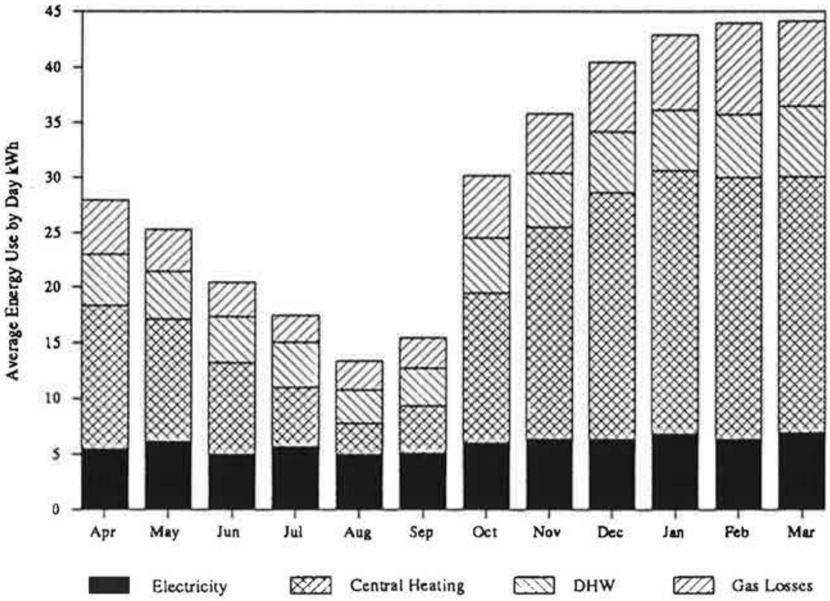
Annual delivered fuel use during the monitored year was 10896 kWh. Of this some 6530 kWh was used for space heating. This was good considering that domestic hot water could not be produced independently of space heating, and, the average internal temperatures maintained by the occupant. The figures compare favourably to average figures for the type and size of dwelling.



Annual Disaggregated Energy Use Total = 10896 kWh

The house made good use of solar gains to displace space heating. Without solar gains gas use for space heating would have been some 30% higher. Due to a control system that necessitated the space heating coming on at times when domestic hot water alone was required, space heating was used throughout the monitored year.

Heat Loss Coefficient	125.5 W/°K
Effective Solar Aperture	4.08 m^2
Solar Displaced Space Heating	30.2 %
Solar Contribution	15.5 %



MONTHLY DISAGGREGATED ENERGY USE

Occupancy : typical of that for a single professional person working in the same general area of London in which they lived.

Annual Disaggregated Energy Use

	Delivered kWh	P.E.U kWh
Radiators	5174	5588
DHW	1735	1874
Losses	1810	1954
Total Gas	8719	9416
Ring	619	2309
Lights	425	1585
Cooking	1133	4226
Total Electric	2177	8120
TOTAL	10896	17536

P.E.U. conversion factors

Gas 1.08 Electricity 3.73

Vertical Solar Radiation per Month

Month	kWh/m²	w/m²/day (mean)
April 1987	55.0	76.4
May	59.7	80.2
September	54.5	75.7
October	46.4	62.4
November	17.3	24.0
December	13.9	18.7
January 1988	22.7	30.5
February	41.0	58.9
March	35.2	48.9
Total	345.7	
May, Sept - March		49.9

Solar Displaced Space Heating SDSH

The amount of space heating displaced by solar gains. Expressed as :-

$$(SG/SH) * 100 \%$$

Solar Contribution SCON

The relative contribution of solar gains to the overall heat input to the building. Expressed as :-

$$(SG/(SG+SH+IG)) * 100 \%$$

SG	Solar Gains
SH	Space Heat
IG	Incidental Gains

Average Temperatures :

Month	External C°	Internal C°
April 1987	11.2	19.9
May	11.1	20.5
June	14.7	21.5
July	17.5	23.1
August	17.1	22.9
September	14.8	21.7
October	10.7	20.8
November	6.7	18.9
December	6.3	18.3
January 1988	5.8	18.4
February	5.0	18.5
March	6.8	19.3
Heating Season	8.5	19.6
Year Average	10.7	20.4

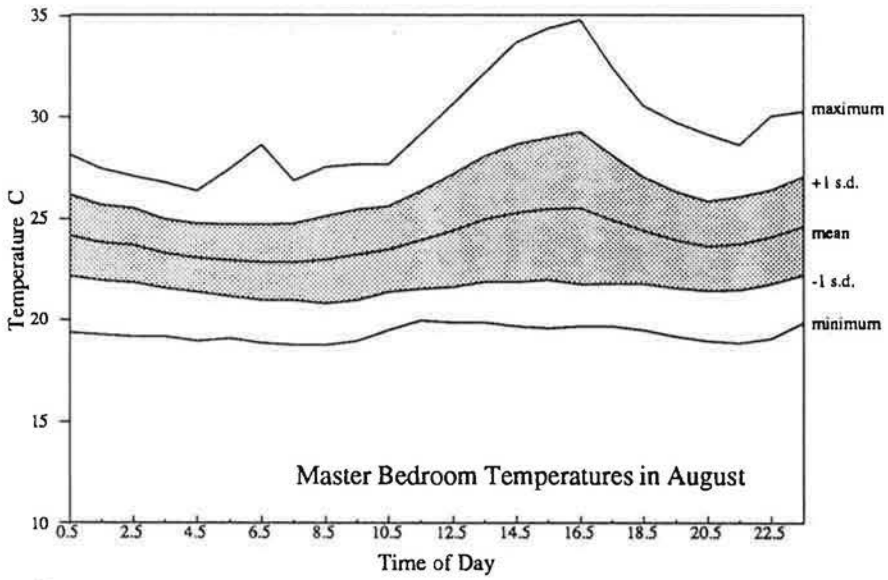
SPECIFIC MEASURES AND FEATURES

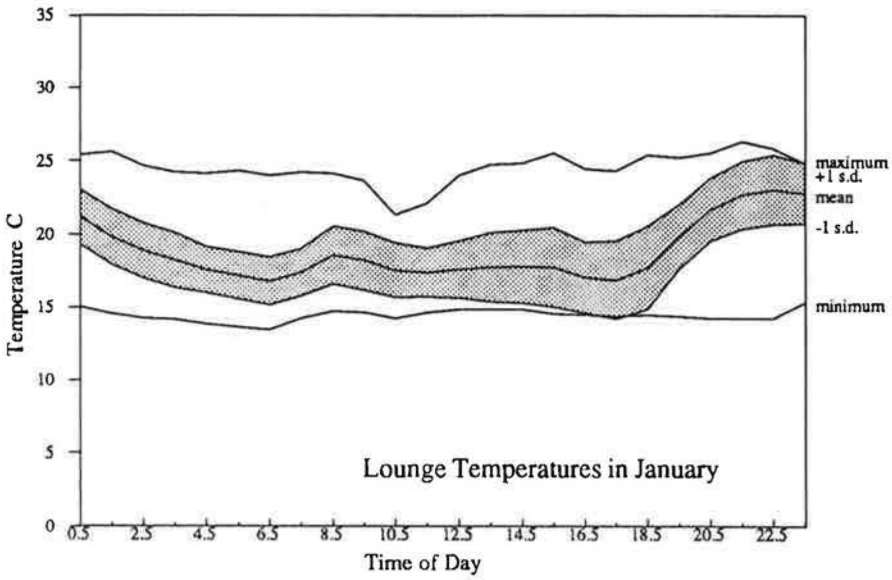
The conservatory combined with the accumulation wall, which was intended to store heat for later use in the bedroom, provided a useful buffering effect which reduced fabric heat loss and was also able to preheat air for ventilation. The use of preheated air to displace space heating was unfortunately limited in practice due to the absence of a finely controlled means of ventilating the air from the conservatory to the living spaces.

There was a bias of glazing in favour of the south facade. Whilst this would act to reduce heat loss through the north elevation it resulted in lowered daylight levels in north facing parts of the house.

TEMPERATURES

Continuous measurements over the course of the year indicated a fairly well controlled environment with only limited occurrences of uncomfortably low or high temperatures, most of which occurred outside of the typical occupancy period.





PERFORMANCE

AMENITY

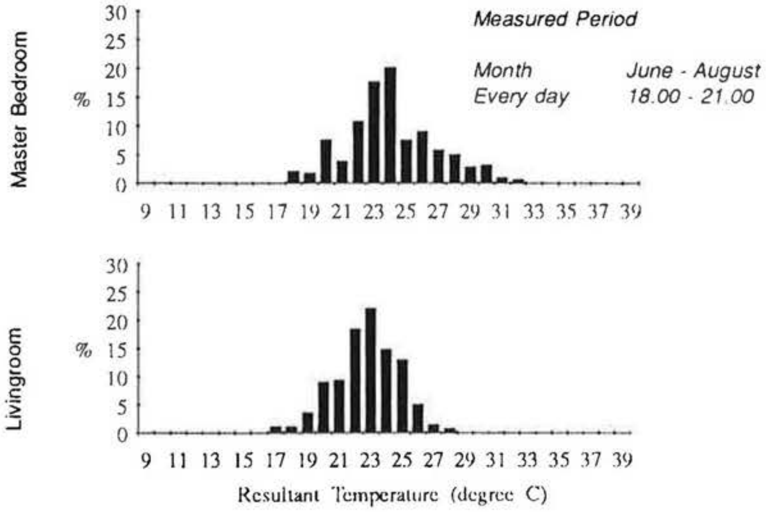
The house was, according to its owner, a very attractive building to live in. In particular the two storey triangular conservatory contributed strongly to the building's distinctive external appearances and enhanced the quality of the environment indoors. The house was not purchased for its energy saving features but for the discernible amenity benefits that the principle feature, the conservatory, offered.

> *"I think that the sunspace is very attractive with all the plants and the sense of greenness..... a very pleasant part of the home. That's what attracted me initially to the house, the idea of the sunspace and knowing what I could do with it."*

On purchasing her home the occupant was only vaguely aware that the building possessed energy saving features and it was not until after a year of occupancy that she managed to obtain the instructions on how to make best use of these features. Despite their apparent simplicity the occupant found the instructions slightly hard to understand, something which may have contributed to her only partial adoption of the designer's intended control regime to make best use of solar energy.

The occupant found the house comfortable although there were occasions when upstairs bedrooms were felt to be cold. In some contrast to recorded temperatures virtually no overheating was reported by the occupant, even in the conservatory. At those times of the year when the conservatory was at its hottest the occupant came home and opened windows and doors and found that a very comfortable temperature could be achieved in the house within a short time (see histograms below).

Whilst the amount of daylight in south facing rooms was satisfactory the occupant was critical, throughout the year, of daylight levels in north facing rooms. Even given its prominent position in Spinney Gardens the house was found to be private. The large window area on the south side of the house was not felt to present an exceptional security risk.

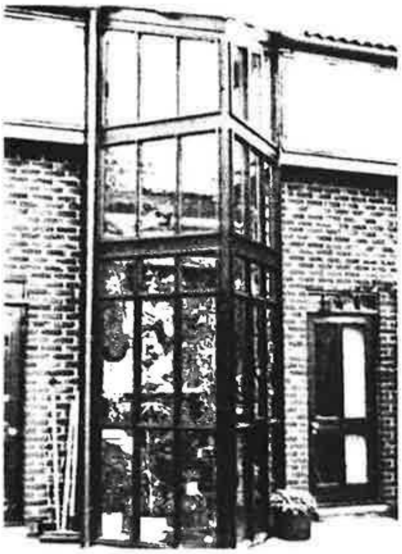


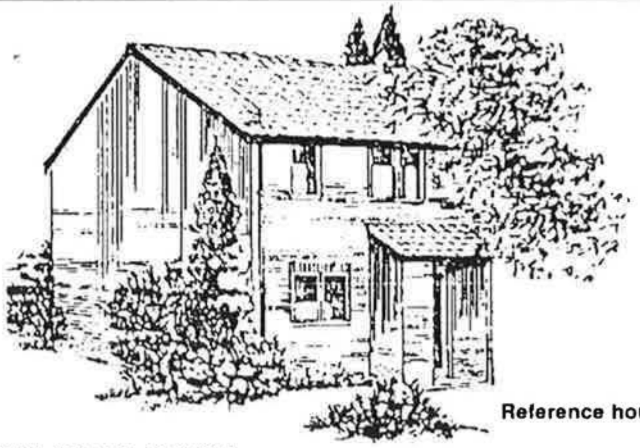
Histograms of summer evening temperatures in the master bedroom and living room

Occupant's rating of their home

FEATURES	Start of study	End of Study
Its thermal comfort	3	4
Effort needed to keep the home warm in winter	2	4
Effort needed to keep the home cool in summer	4	4
Adequacy of heat distribution throughout the home	2	3
Quality of the air indoors	4	4
Soundproofness from outside noises	3	3
Amount of daylight entering north facing rooms	3	3
Amount of daylight entering south facing rooms	4	4
Extent of the view of outside from indoors	4	3
Its privacy from outside viewers	4	4
Its standard of construction	3	2
Its general character and 'atmosphere'	5	5
Its external appearance from the south	5	5
Its external appearance from the north	4	4
Its internal appearance	5	5
Its internal layout and design	4	4
Its resaleability	5	5
Its heating costs	4	4
OVERALL	5	5

Score : 1 - Very unsatisfactory 5 - Very satisfactory



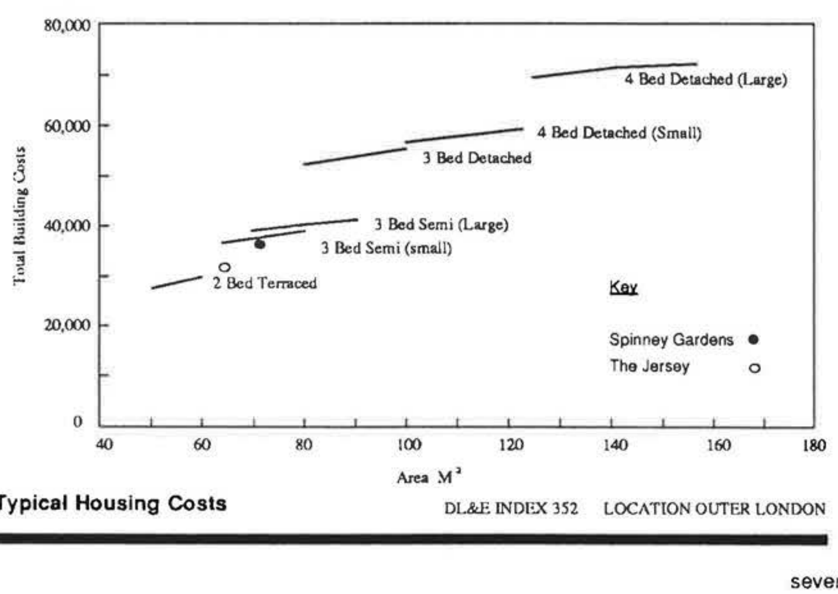


Reference house : The Jersey

BUILDING COST

Spinney Gardens and a comparable reference house were costed by Davis, Langdon and Everest using a standard elemental method which does not take account of the actual costs of the constructed building. The reference house, the "Jersey" by Matthew Homes, was chosen by D,L&E to provide a comparison in terms of what a purchaser might have bought as an alternative to Spinney Gardens. The costings used a base date of the 2nd quarter 1989, an Outer London location, and included an adjustment for differences in Gross Floor Area between the buildings. Spinney Gardens was estimated to cost £36,804 (£518/m² - 71/m² GFA, including conservatory and porch) in comparison to the Jersey which cost £32,400 (£506/m², 64 m² GFA, no conservatory). The modelled cost of Spinney Gardens was beyond the upper limit of the quantity surveyor's reference range.

The additional cost of Spinney Gardens should be viewed within the context that the houses were constructed in accordance with the stringent conditions of the low cost housing competition that they won. Furthermore, despite the high estimated cost the houses originally sold well in a competitive market, some being resold after a year of occupation for a considerable profit. Additional real costs, if any, can also be traded-off against the special amenity and energy benefits that the design provides and the additional floorspace provided by the conservatory.



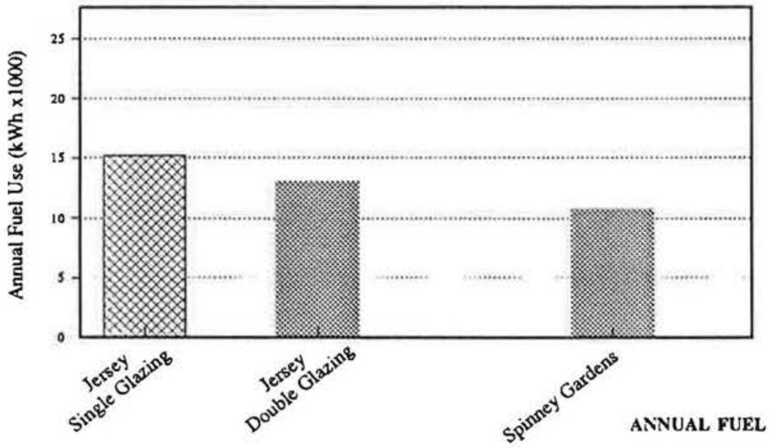
Typical Housing Costs

DL&E INDEX 352 LOCATION OUTER LONDON

PERFORMANCE

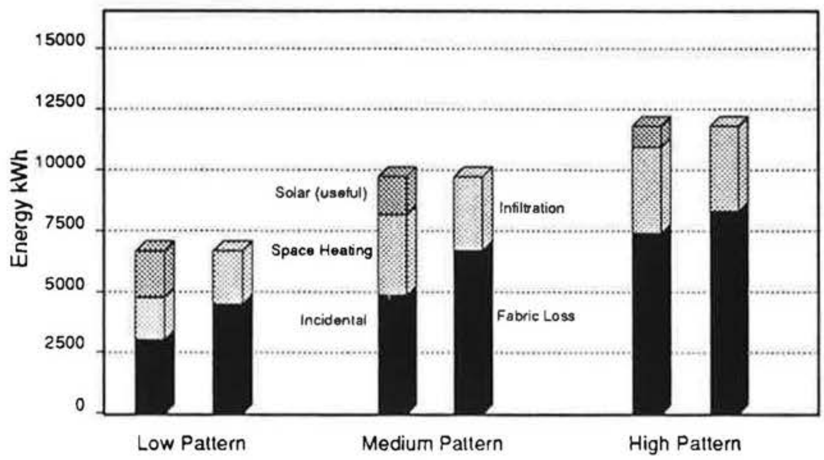
DESIGN STUDY

In order to assess the energy performance of Spinney Gardens the building was compared to the Jersey (see Cost Section) using the well established model BREDEM. The reference design was modelled for the same occupancy as Spinney Gardens, insulated to the same level, heated to the same temperatures, enjoying the same orientation, degree days and solar radiation. The reference house was evaluated twice, once for single and once for double glazing. From the simulation it was clear that, for the same conditions and insulation levels, Spinney Gardens had a better energy performance than the standard house design, even when that design was upgraded to include double glazing.



ANNUAL FUEL USE

Using a more advanced computer model (HTB2) a series of simulations were performed to test the sensitivity of the Spinney Gardens design to different types of occupancy and to investigate the performance characteristics of specific design measures. The HTB2 simulations showed that as the occupancy pattern intensified the useful solar contribution reduced, mainly because of the high level of internal incidental heat gains. All the main solar measures in the house (the conservatory, accumulator walls, glazing ventilation) were found to enhance the energy and environmental performance of the house. In particular, the buffering effect of the conservatory was predicted to contribute a significant energy saving. This supports the findings from the energy monitoring.



MODELLED ANNUAL ENERGY PERFORMANCE FOR DIFFERENT OCCUPANCY PATTERNS

	Jersey : Single Glazed	Jersey : Double Glazed	Spinney Gardens (Monitored)
Average internal temperature °C	20.4	20.6	20.4
Space Heating Output kWh/year	8140	6556	5174
Space Heating Fuel kWh/year	11334	9112	6529
Total Fuel kWh/year	15279	13057	10896

BREDEM Analysis

EVALUATIONS

The evaluations are based on 12 months monitoring, interviews, questionnaires, and modelling studies. For ease of comparison with other studies in this series, the performance of the building has been summarised under the four headings in the following way. Five stars indicate an excellent, three an average, and one a poor standard.

Energy ★★★★

The design has the potential to be a good energy performer. The buffering effect of the conservatory provided an estimated 20% energy saving mainly due to reduced fabric losses. A significant area of energy inefficiency was the poor heating system controls which provided heat to the house when only hot water was required, even in summer.

Solar Design ★★★★

The house had a reasonable solar performance in terms of displacing space heating. The solar feature was the conservatory which used solar gains indirectly acting as a buffer space and providing ventilation preheat. The buffering effect proved highly successful. However, the potential for ventilation preheat was limited by the fact that the air flows between the conservatory and the bedroom relied upon occupant intervention. This was incompatible with the typical occupancy pattern of the householder

Amenity ★★★★★

Given the occupant's very high regard for the house as a place to live in and own and her views about its running costs the building is awarded the highest rating for amenity. The marginal underheating reported was not thought sufficient to detract from this. The occurrence of high temperatures, mainly during unoccupied times of the day, demonstrated that the design was sympathetic to the typical occupancy profile for the type of dwelling. The rating is further justified by the building's marketability which the occupant thought was excellent.

Cost ★★★★

On face value, using modelled costs, the house was a below average performer. However, for the additional cost the purchaser would enjoy the spatial and substantial amenity benefits of $7m^2$ of conservatory, which the reference design does not possess. Furthermore, the modelled costs possibly do not do full justice to the actual building which was constructed within the very tight constraints of a major developer's low cost housing competition.

Composite ★★★★

For its market sector the building offers an interesting and acceptable alternative to more traditional designs and would, from its owner's viewpoint, appear to offer excellent value. The only significant problems were the poor heating system control, and, the absence of non-occupant dependent openings between the conservatory and the living spaces which, if present, might have enabled better use of the preheated air in the conservatory.

ASSESSMENT

LESSONS and RECOMMENDATIONS

1. The conservatory provides a significant energy saving benefit to the house, mainly through its buffering effect which reduces fabric heat loss. It has the potential to preheat air for ventilating the house, however, in its current configuration the occupant has to open doors to fulfil this strategy. A more suitable design would be to provide a more finely controlled form of ventilation so that it could operate relatively independently of occupancy and security considerations.

2. In designing a low energy passive solar building it is essential that design effort is applied equally to the environmental services and the form and fabric of the building. This project has demonstrated that the full energy benefits of the design were not achieved due to an inappropriate control mechanism which maintained a live heating circuit when only hot water was required.

3. Conservatories of the Crystal Palace type offer a very good means of harnessing the energy benefits of solar gains whilst avoiding overheating. At the same time the feature is ostensibly an amenity rather than an energy feature, attracting potential house purchasers who might not normally be concerned with purchasing a particular house because of its energy saving measures.

4. Where a house requires occupant actions for the fulfilment of its energy strategy it is important that special effort is made to communicate the timing and nature of such actions to current and future occupants.

5. The conservatory provided a suitable intermediate space which extended the period when the occupant enjoyed the benefits of outdoors without the associated discomfort. A conservatory is a passive solar feature that successfully combines energy efficiency with amenity.

CONCLUSIONS

The house is a success, representing a careful balance between the cost constraints of low-cost starter homes whilst providing the occupant with considerable amenity value for their money and the added bonus of good energy performance.

This small development demonstrates that passive solar design is not simply a discipline for larger houses but that with diligence designers can apply the principles to mass housing.

One reservation expressed elsewhere by estate agents is that owners in this sector of the market will not be able to afford the long run maintenance costs of large passive solar features, with a subsequent deterioration in their visual and energy performance. This question was not addressed in this study and remains to be answered.

A further question, not addressed in this study, concerns whether the unique visual aesthetic of such buildings will endure as a marketable factor.

FURTHER INFORMATION

EPA Technical Report: Spinney Gardens 1990. ETSU Report - 1163/7

Best Practice Programme of the Energy Efficiency Office, BRECSU, BRE.

Solar Building Studies are summary reports of the Energy Performance Assessment project. This is funded by the Department of Energy through its' Energy Technology Support Unit at Harwell. The R&D is carried out by Databuild (Birmingham) and UWCC (Cardiff). The views contained in this document are those of the authors. The EPA of Spinney Gardens was carried out by UWCC (Cardiff).

The co-operation and assistance of all those concerned with the building reported here is gratefully acknowledged : owners, operators, designers and occupants.

"This report is one in a series of 30 buildings being studied. For further information on this and the other buildings, please write to: "

RENEWABLE ENERGY ENQUIRIES BUREAU
ETSU
HARWELL
OXFORDSHIRE OX11 0RA

Tel: 0235 (432450)
Fax: 0235 (433131)