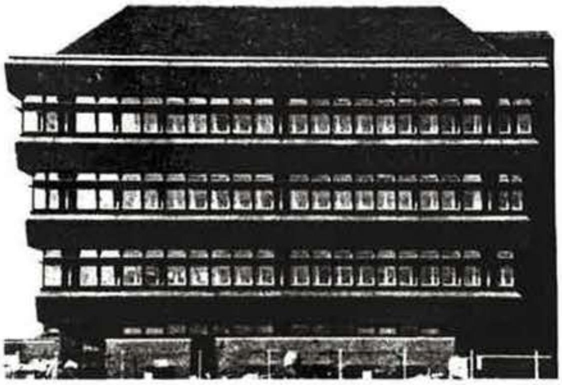
SOLAR ENERGY
A Renewable Energy

Summary Report



South Staffordshire Water Company

ETSU S 1160/SBS/4

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views and judgements
expressed in
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Department of Energy.

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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

SOUTH STAFFORDSHIRE WATER COMPANY

ENERGY PERFORMANCE ASSESSMENTS

Client:
South Staffordshire Water Company

Architect
Harry Bloomer Partnership

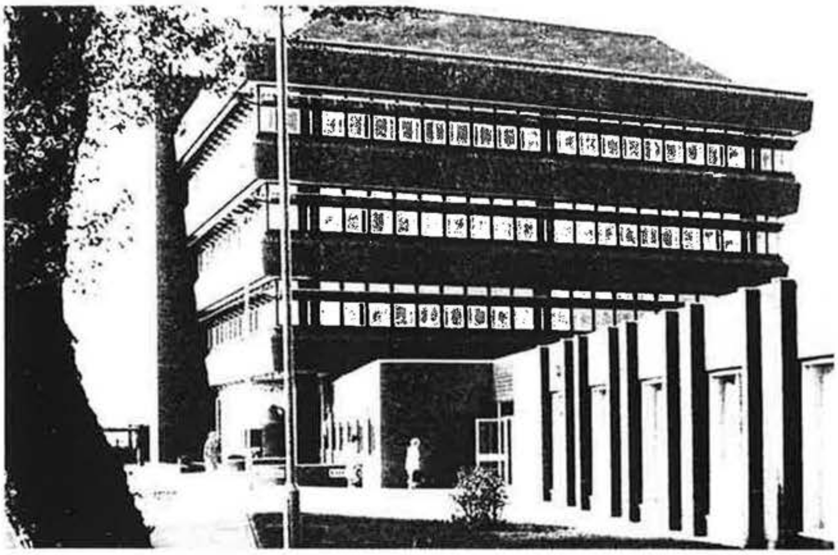
Building Type:
Office Block

Solar Features:
Large Glazing Areas and Light Shelves

Location:
Semi-urban, Walsall, West Midlands

Date Occupied:
1985

Size:
Gross Floor Area 3833m^2



Light shelves eliminate summertime overheating and improve the daylighting of the offices.

Electricity lighting use in offices was low, typically 9.5 kWh/m^2 pa in offices.

Total annual energy use for the building was low at 130 kWh/m^2 gross floor area.

The passive features contribute to a high degree of user satisfaction.

The electric lighting control logic could be improved to benefit users and increase energy savings.

The passive features have been incorporated at little extra cost to the overall building.

EVALUATIONS

ENERGY	★★★
SOLAR DESIGN	★★★
AMENITY	★★★★
COST	★★★

These ratings are based on 12 months monitoring, interviews, questionnaires, and modelling studies. Five stars indicate an excellent standard, three an average, and one a poor standard.

ETSU-1160/SBS/4

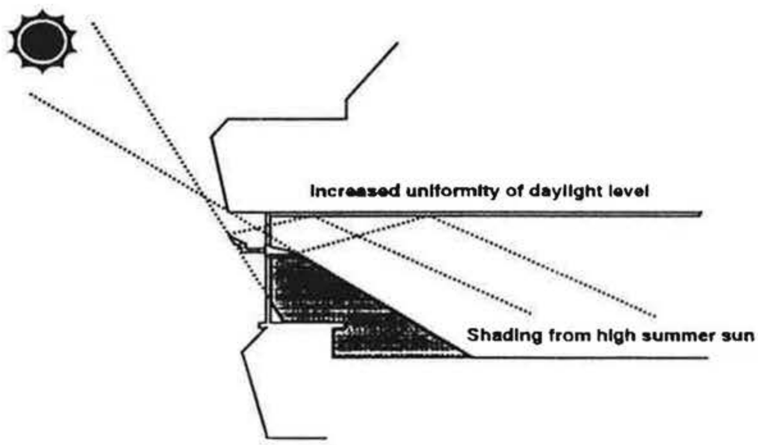
THE BUILDING

DESIGN

The brief was for about 3000m^2 of office space, as part of the company's rationalization plan to centralise previously scattered accommodation. The client required a low energy building with high levels of daylighting and natural ventilation. A further requirement was that occupants should have a high degree of control over their environment. Adjacent buildings and poor ground conditions dictated that the building had a small base area.

To meet the daylighting criteria, preliminary designs incorporated tall ceilings and large windows. The problem of summertime overheating inherent in this design approach led to other solutions being sought.

The eventual solution was an inverted pagoda form with a continuous band of fenestration on each floor. Each storey overhangs the one below it and hence provides some shading of the windows which reduces the solar heat gains. Interior and exterior shelves were added to further increase the shading. These shelves were also designed to improve daylight distribution in rooms by reflecting daylight deep into the room. Openable windows provide natural ventilation.



DESCRIPTION

FORM

There are four storeys plus an attic and mezzanine based on a square plan. The top three floors provide the new office accommodation, whilst the ground floor adjoins the existing building and contains the reception, restaurant, main frame computer and post sorting rooms. The attic which is used for archives, acts as a thermal buffer zone. An 8m x 8m central core is used to distribute services and contains the toilets and fire escape stairs.

Energy Consultant
Databuild Ltd.

Services Engineer
King Cathery Partnership

Site Data
Latitude 52.6°N
Altitude 162m

Climate Data
Degree Days

Heating Season:	
1987/8	1984
20 year average	2075
Annual:	
March 1987- Feb 88	2452
20 year average	2495

Techniques used to optimise benefits were:

- Low emissivity glazing in high performance frames.
- Combined light shelves and external shades at high level to redistribute daylight.
- High mass, low level internal sill to absorb solar gain.
- High insulation of opaque elements.
- Manual and automatic control over the lighting and space heating.

Dimensions:
Floor to ceiling height: 3m

Floor Areas: m^2

Ground Floor	- 985
inc. Comp suite	- 170
Mezzanine	- 287
First floor	- 595
Second floor	- 645
Third floor	- 696
Attic space	- 625

Volume:m^3

Gross	- 14,265
Heated	- 12,390
Attic Buffer	- 1,875

THE BUILDING

U - Values: W/(m²K)

Floor	- 0.35
Wall	- 0.20
Window\(incl frames)	- 1.60

Envelope Heat Loss: kW/K

Transmission	- 2.1
Infiltration/Ventilation	- 3.0

Glazing Properties:

Double glazed, low emissivity, argon filled (12 mm)

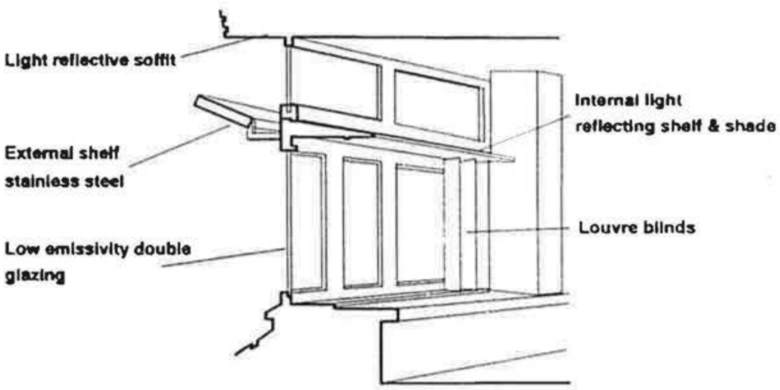
U - Value	- 1.6 W/(m²K)
Daylight Trans	- 60%
Solar Trans'	- 59%
or if reversed	- 69%

CONSTRUCTION

An in-situ concrete frame was used with reinforced concrete cladding panels and a facing brick finish. The ground floor section adjoining the existing building was traditional masonry construction. The building is well insulated with the external walls having 100mm ureaformaldehyde and insulating blocks, whilst the overhangs included spray on insulation (150mm poly-isocyanurate) against cold bridges. The ground floor is insulated with 75mm polystyrene, and the pitched roof is insulated in the attic floor with 100mm polystyrene.

PASSIVE FEATURES

Large areas of low emissivity glazing are mounted in high quality UPVC frames of low U value and negligible air permeability. The frames incorporate internal and external light shelves to achieve the design intentions.



SERVICES

Space heating uses central modular gas boilers supplying low pressure hot water to constant and variable temperature systems. The variable temperature circuit comprises a weather compensated radiator system with four zones per floor. All zones are controlled by thermostats through a central building energy management system (BEMS) and the radiators have thermostatic valves. The constant temperature circuit provides domestic hot water throughout the building and supplies heat to the heater batteries in the toilet ventilation systems and the ground floor reception area. The constant circuit also provides heat to areas outside of the new office building.

Lighting in offices comprises recessed ceiling luminaires providing 350 lux, with task lights where higher light levels are required. Ceiling luminaires are controlled via the BEMS using a combination of time and external light levels, the latter are measured on eight roof mounted sensors (two on each façade). Users have limited control and can only switch lights on when the BEMS decrees that they are available, but lights can be turned off at any time. Some luminaires are in use throughout the working day to provide background lighting.

Space Heating
Installed Capacity:

Heated Areas	- 50 W/m²

Design Condition:

Internal Temp	- 20°C

Lighting
Installed Capacity:

Offices: Ceiling	- 10 W/m²
Task	- 16 W/desk

Design Condition:

Offices	- 350 lux
Circulation	- 250 lux

Ceiling Luminaires:

600 mm recessed fittings each including three T8 linear fluorescent tubes (correlated colour temp 4000 K, colour rendering index Ra 85). Power use is 75 W per fitting.

PERFORMANCE

ENERGY AND ENVIRONMENT

All figures and observations are based on a monitoring period of 12 months from March 1987 to February 1988 inclusive. Space heating use has been normalized to local 20 year average degree day data.

FUEL USE

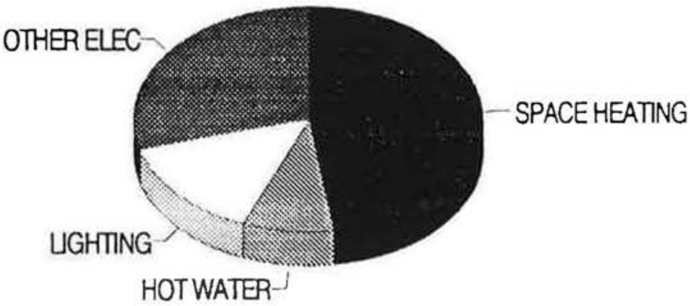
The actual delivered gas for the new office building alone could not be measured, as the boiler room also serves adjoining buildings. However, by using the derived system efficiency (57.5%)* and monitored energy use, an approximate figure for gas use for the new building was obtained.

The total delivered energy of 128 kWh/m^2 pa (based on the gross floor area 3833 m^2) compares favourably with DoE PSA performance indicators for naturally ventilated offices (< 5000m^2) where good is less than 230 kWh/m^2 pa.

DISAGGREGATED ENERGY USE

The delivered gas for the new office building alone could not be measured consequently the values below are for normalized actual energy uses within the new building. The major functions were obtained through direct monitoring. Some ancillary functions (ie DHW) were derived using information supplied by BRECSU for buildings of a similar size and type.

FUEL TYPE	FUNCTION	NORMALIZED ENERGY (kWh pa) Total	/m^2
Gas	Space Heating[1]	110 040	39
	Space Heating[2]	61 860	155
	Hot Water[2]	29 250	
Electricity	Lighting[3]	50 670	16
	Other Uses[4]	92 740	
Gas & Electricity Total[5]		344 560	90



FUEL TYPE	NORMALIZED DELIVERED FUEL (kWh pa) Total	/m^2
Gas	349 820	91
Electricity	143 410	37
Total	493 200	128

* The system efficiency was derived from the simple relationship between gas delivered to the boiler and the energy use of all of the functions serviced by it. The efficiency is quite low due in the main to services outside of the main building.

PSA Performance Indicators
Naturally Ventilated Offices < 5000m^2
Whole Building Energy

	kWh/m^2 pa
Good	< 230
Fair	230 to 289
Poor	289 to 359
Very Poor	> 359

Monitored Building
BRE Low Energy Office : 143

1 Space heating for the offices is provided by the variable temperature circuit, and is apportioned over 2808m^2 (building heated area minus the reception area and toilets.

2 Space heating for the reception area and toilets (400m^2), and domestic hot water are provided by the constant temperature circuit.

3 Lighting is apportioned over the heated floor area 3208 m^2 (all except the roof space).

4 Other electric uses include, lift and mail sorting machinery commensurate with 1¼ million customers, as well as the more normal photocopiers, vdu's and task lighting.

5 Total energy use within the building is apportioned over the gross floor area. 3833 m^2.

PSA Performance Indicators
Naturally Ventilated Offices < 5000m^2
Space Heating and DHW

	kWh/m^2 pa
Good	< 209
Fair	209 to 259
Poor	259 to 320
Very Poor	> 320

Monitored Building
BRE Low Energy Office : 125

Energy Efficiency Office
Electricity (for uses other space heating, mainly lighting)

	kWh/m^2 pa
Good	< 23.9
Satisfactory	23.9 to 29.0
Fair	29.0 to 44.4
Poor	44.4 to 68.3
Very Poor	> 68.3

Monitored Building
BRE Low Energy Office : 4.7

SPACE HEATING

Space heating, which maintains an average internal temperature of 20 to 21°C, has a low energy use with a short heating season Oct-April. The variable temperature heating system, which serves all offices and the upper floor stair landings, provides 39 kWh/m^2 pa to the perimeter radiators in these areas. In contrast the constant temperature system provides about 155 kWh/m^2 pa to the heaters and mechanical ventilation systems in the ground floor reception area and toilets. This is due in part to the higher air change rates. The average building use was 53 kWh/m^2 (equivalent to 92 kWh/m^2 delivered energy).

LIGHTING

Electric lighting for all areas including the non-daylit areas such as the central core, circulation areas and the frequently used attic space, was measured to be 16 kWh/m^2 pa. This compares well with EEO guidelines, which indicate that electricity uses (for other than space heating, ie. mainly lighting) of 23.9 kWh/m^2 pa or less is "good". Observed use of task lighting was negligible.

Interest in the daylight features and displaced electric lighting led to the building being used in a collaborative US/UK project between Databuild (UK) and the Lawrence Berkeley Laboratory (USA). Daylight availability and electric lighting usage data from the monitoring period (April to June) were used as calibration input to the jointly developed Daylight Performance Evaluation Methodology (DPEM). DPEM was designed to predict artificial lighting usage in buildings which use daylighting strategies to reduce artificial lighting demand. Results from this show a very good correlation between evaluated and monitored data. The calibrated model was then used with a 12 month solar radiation database to predict annual office lighting use. The prediction for the second floor office was 9.3 kWh/m^2 pa.

Monitoring results for April '87 show that during normal working hours, in second floor offices, the average light level was >500 lux. This indicates that a low lighting load was achieved without detracting from the level of light within the offices.

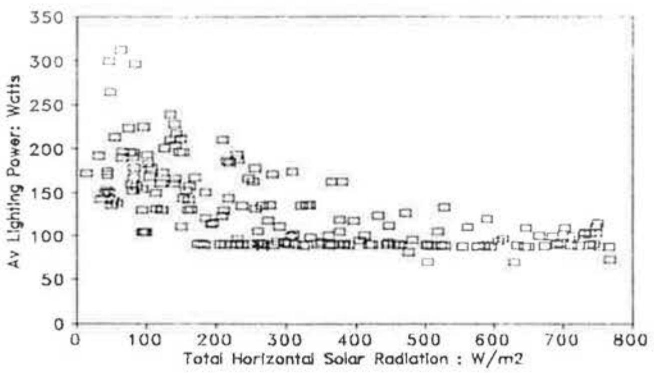
PASSIVE SOLAR FEATURE

The light shelves make the light levels within the offices more uniform by an apparent redistribution of light within the room. This was achieved by reducing the brightness of areas near the window and not, as was the design intention, by reflecting light deep into the room. The shading effect of the shelves was successful in reducing summertime overheating.

Monitoring results, as shown in the figure, broadly show that the use of electric lights reduces as the external luminance increases. It is clear though that there is still potential for reductions in usage, improvements in the control software could reduce the existing unnecessarily high base level.

PERFORMANCE

Variation of Electric Lighting with External Illuminance

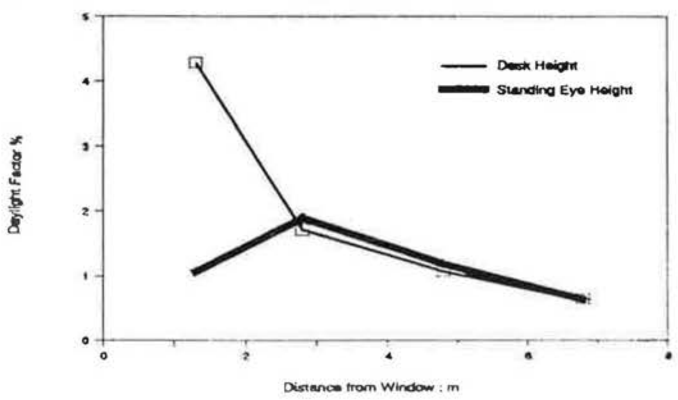


Over the monitored period the electric lights were shown to have an unnecessarily high base load regardless of the exterior luminance level.

DAYLIGHT FACTORS

For overcast sky conditions the average daylight factor in offices at desk height (0.7m) was about 2%. This is consistent with daylight being the principal source of illumination, as stated in the current CIBSE Lighting Code (1984). The minimum daylight factor was about 0.7%, giving a uniformity (minimum/average) of 0.35. At standing eye height (1.55m) daylight factor measurements show that the light shelves reduce light level near to the window, thus improving the uniformity of light within the office.

Daylight Factor Profiles



AMENITY

Questionnaires completed by the buildings occupants reveal that:- The solar shading and precautions against summertime overheating have worked well, maximum recorded internal temperatures were about 24°C. The occupants are pleased with the daylight features and agree that they work well. However there is some dissatisfaction with the electric lighting controls and complaint of glare through the unshaded top windows.

BUILDING COST

The building is principally new build but includes some refurbishment in the link with the existing building. The final building cost of £1 790 306 (£467/m^2 gross floor area), is within, but towards the high end of, the BCIS band of costs for typical offices. The building however has high quality finishes throughout. The windows accounted for 8% and the internal and external light shelves accounted for a further 3% of the total cost.

Design Occupancy
No. 160

14m^2 office space/person

Functions
Senior Management
Administrative
Accounting
Engineering
Computing

Building Cost (1985):
£467/m^2 gross

Typical Office Costs (1985):
Medium height and quality
£420 to 500/m^2

EVALUATIONS

The star ratings are evaluations based on all of the information gathered during the period of study, and are brought together here to give a comprehensive judgement of the building. Five stars indicate an excellent standard, three an average, and one a poor standard.

ENERGY ★★★

This rating is given for the normalized total delivered energy use, which at 128 kWh/m^2 pa compares well with published PSA performance indicators which state that total delivered energy use of below 230 kWh/m^2 is good. The monitoring reveals though that with improved design and control of the systems, the energy performance could be improved.

SOLAR DESIGN ★★★

The initial design brief was to minimise electric lighting usage by utilizing daylight, whilst also avoiding the normally inherent summertime overheating. Internal and external light shelves were employed to achieve these aims. The design intention of reflecting daylight deep into the rooms was not achieved. However the shelves shaded areas close to the windows making light levels within the office more uniform and simultaneously reducing solar heat gains. A control system using external photocells restricted the use of electric lights when it deemed they were unnecessary.

AMENITY ★★★★

The environment appears to be well liked by the occupants. The solar feature helps to provide an acceptable level of uniform light in the offices, however problems with glare were reported. Temperatures are stable and comfortable throughout the year.

COST ★★★

The cost of the building, which has a high quality finish throughout, compares well with similar size office blocks. This indicates that the solar features are incorporated at little additional cost.

COMPOSITE ★★★

The energy performance of the building was good and was achieved with little extra cost to the building construction. The solar design proved to be successful in providing an overall good quality of light within the offices with a low electric light use. However BEMS control of the lighting and other building services was poor restricting potential energy savings.

ASSESSMENT

CONCLUSIONS

By using passive systems the design team have produced a building with good utilisation of daylight within a low heat loss envelope. Consequently heating and lighting energy use is low. Monitoring suggests that further energy savings could be obtained by adjustments to the energy management systems controls over electric lighting. Both the client and users are pleased with the way the building performs. The building's cost compares favourably with typical costs for similar buildings, suggesting that the energy saving features have not increased the overall cost of the building.

LESSONS & RECOMMENDATIONS

The comments below relate to information obtained from the Energy Performance Assessment and represent the views of the monitoring team.

1. Light shelves can be used to provide solar shading and simultaneously an apparent increase in internal light quality by creating a more uniform distribution of daylight. However, provision for some shading from intermittent isolated glare should be made, although this could affect the efficiency of the light shelves.

2. Since the building is designed to be well daylit, then adequate controls should be used to limit the amount of electric lighting used and fully exploit the available daylight. This building maintained an unnecessary base load of lighting, a reduction or even elimination of this when daylight in the offices was sufficient would have naturally reduced the total lighting load.

3. Attention should be given to each of the buildings services. This will prevent one aspect from dominating the strategy. In this building the constant temperature system ran continuously to supply an air conditioning plant (outside of the defined building), which adversely affected the whole boiler system efficiency.

FURTHER INFORMATION

EPA Technical Report on the SSWC building, available from ETSU. ETSU Report 1160/4

L J Heap, J Palmer, A Hildon. 'Redistributed Daylight -A Performance Assessment'. National Lighting Conference 1988, (CIBSE), Cambridge UK, March 1988.

'Low Energy on Tap.' Building Services Journal, December 1986.

'US/UK Daylighting Performance Evaluation Methodology - Final Summary Report, draft November 1987. Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720.

BRECSU Best Practice Programme

ETSU Renewable Energy Enquiries Bureau: Telephone: 0235-432450.

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 the JEL building was carried out by Databuild (Birmingham).

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