USING ENERGY FROM THE SUN

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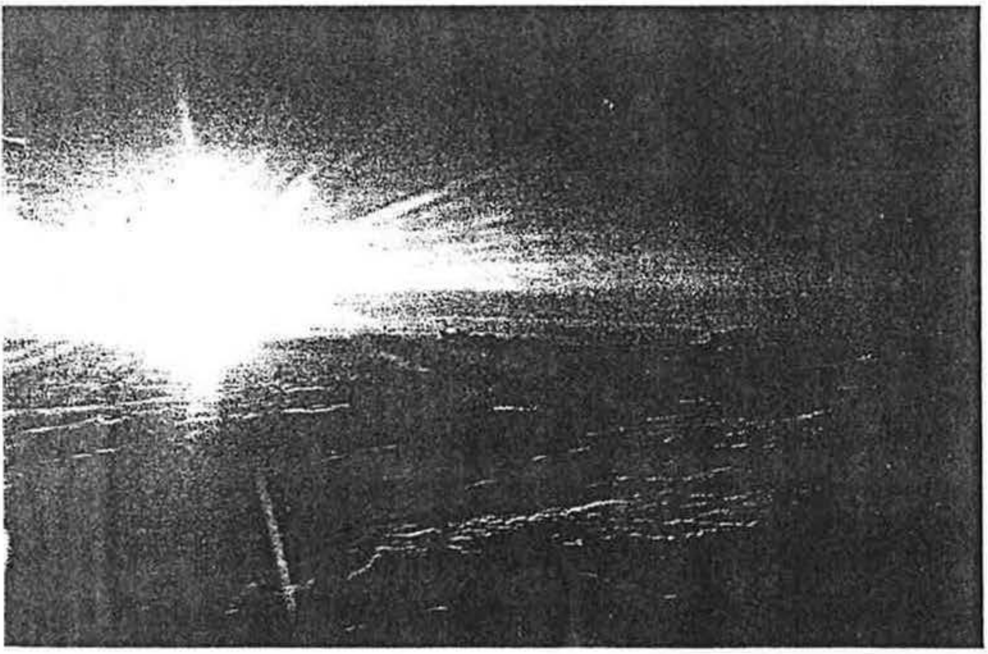
solar energy technology in Britain



SOLAR HEAT
A Renewable Energy

USING ENERGY FROM THE SUN

The potential for using solar energy in Britain is much greater than generally imagined. Indeed recent research indicates that making direct use of the sun's energy, through passive solar design in buildings, is one of the most economically attractive ways of utilising renewable energy in Britain. Passive solar design uses a building's form and fabric to capture, store and distribute solar energy received, thereby reducing the demand for heat and artificial light. At its simplest it consists of siting buildings so that large glazed areas can face south, free from overshadowing, minimising glazing on north-facing walls and incorporating complementary energy efficiency features, such as adequate roof and wall insulation and automatic controls on heating systems. Integrating passive solar design with energy efficiency, as part of good energy practice, maximizes the energy saving and amenity benefits from expenditure on passive solar features and can reduce energy consumption in housing by as much as 50 per cent. It can also lead to substantial energy savings in commercial buildings.

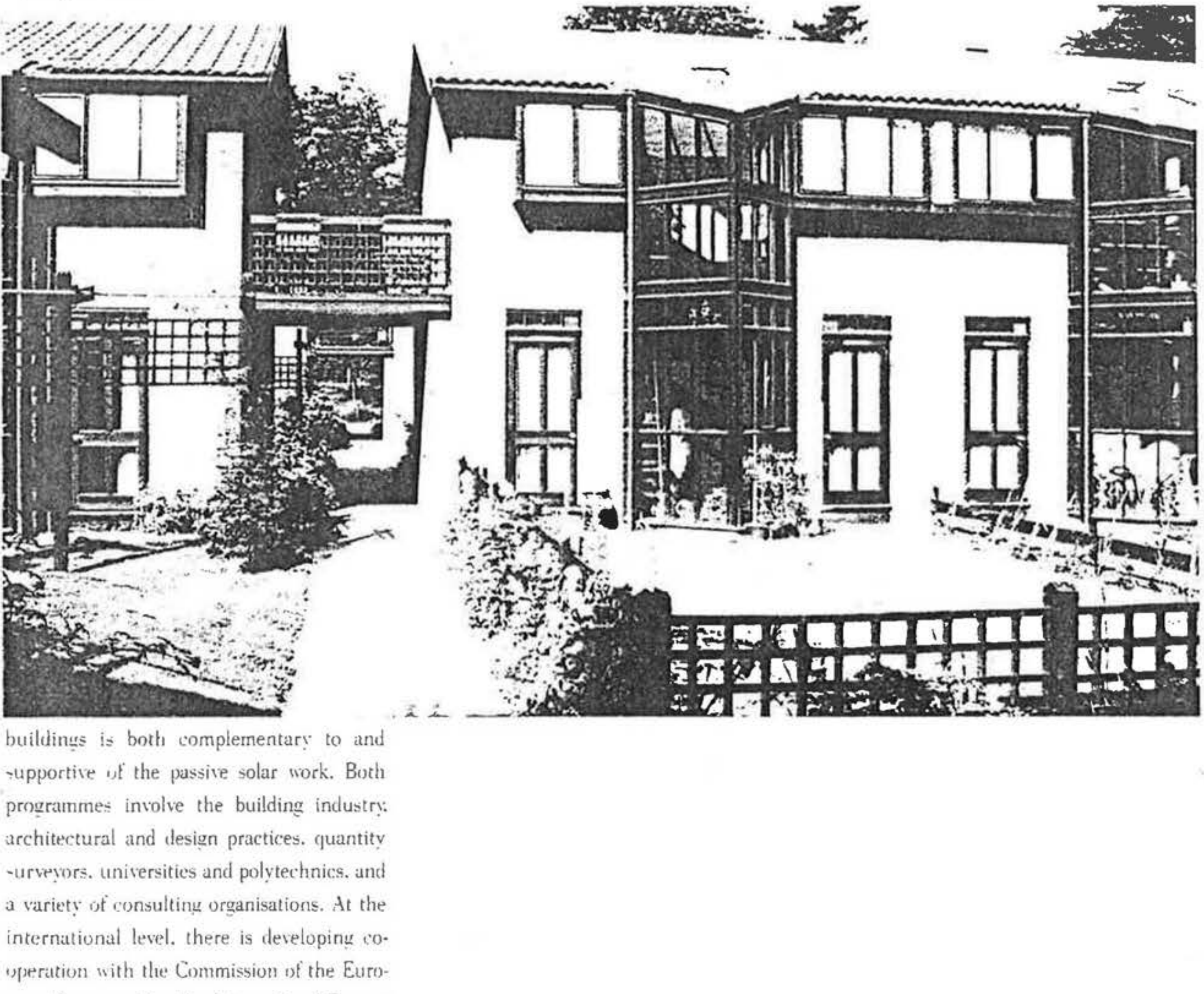
The Department of Energy has been supporting research and development in the field of solar energy since 1977. Initial assessments showed that the direct conversion of solar radiation into electricity, the technology known as photovoltaics, offered little prospect of making an economic contribution to UK energy supplies so the Department decided not to pursue R&D in this area. On the other hand, for seven years, the Department supported a comprehensive programme of R&D on space and water heating systems using roof collectors and a circulating fluid. These are termed active solar heating because the working fluid is pumped round a circuit similar to conventional heating systems. The R&D, however, demonstrated that, apart from special applications such as swimming pools, such systems are unlikely to be cost-effective in British climatic conditions. Passive solar design, by contrast, has been shown to be cost effective to the extent that it is now regarded as one of the most economically attractive renewable energy technologies for UK application.

Energy use in buildings accounts for some 45 per cent of primary energy consumption in Britain at an annual cost of some £13,000 million. Adopting passive solar technology on a wide scale could reduce this figure by as much as £230 million by the year 2025 and by more than four times that amount in the later decades of the next century.

Research and development on passive solar energy technology in Britain is led by the Department of Energy through its Renewable Energy R&D Programme managed by the Energy Technology Support Unit at Harwell. To date the work has cost £3 million.

The passive solar programme maintains links with the buildings R&D supported by the Department of the Environment, the Department of Education and Science and the Energy Efficiency Office of the Department of Energy (EEO), whose R&D on energy efficiency in

Solar designed houses, Spinney Gardens, Crystal Palace, London.



buildings is both complementary to and supportive of the passive solar work. Both programmes involve the building industry, architectural and design practices, quantity surveyors, universities and polytechnics, and a variety of consulting organisations. At the international level, there is developing co-operation with the Commission of the European Communities, the International Energy Agency and the United States Department of Energy.

Simple passive solar technology involves minimal technical risks and adds little or nothing to capital costs but it is not generally understood or widely accepted by the building industry, its clients or the general public. The Department of Energy aims to see passive solar design and cost-effective energy efficiency measures becoming well established in UK building practice by the mid-1990s. If that is achieved, it should lead to substantial long term reductions in the nation's fuel bill.

SOLAR ENERGY TECHNOLOGY

Solar radiation is the primary source for most renewable energy sources. It drives the earth's climatic system and thus gives rise to wind, wave and hydropower. It sustains plant growth and so produces biofuels. The term solar energy, however, is usually taken to refer only to those energy sources that derive directly from the sun's heat and light. It is possible to convert the sun's rays directly into electricity using photovoltaic cells. More commonly, however, solar energy is used as a source of heat and light, the radiation being turned into controlled useful energy by the mechanical heat exchange systems of active solar technology or through passive solar design.

Passive Solar Design

Combined with the appropriate energy efficiency measures, passive solar design makes use of sunlight to heat and light buildings, with little or no mechanical assistance. The adoption of passive solar techniques can substantially reduce the amount of energy needed to operate a building. Incidental heat gains and daylight already make a contribution to the energy needs of most buildings. Passive solar design seeks to optimise that contribution.

Worthwhile improvements in the energy performance of houses can be achieved by arranging windows and skylights to allow solar energy into areas that need to be heated. Such *direct gain* passive designs, which can be constructed at little or no extra cost, typically have large windows on the south side and smaller glazed areas facing north. Another method of capturing solar energy is to add an extra highly glazed unheated room - a *sunspace* or conservatory - to the south side of the house. The sun warms the air in the space, so reducing heat losses from the house. Such sunspaces can provide a pleasant additional living area available for use for much of the year. One of the more complex passive solar design techniques is the *trombe wall* - a very shallow sunspace with a heat collector, usually the house wall, placed one or two feet behind the glazed outer wall. Solar heat is absorbed by the heat collector during daylight hours and released to the interior of the building by radiation and convection at night.

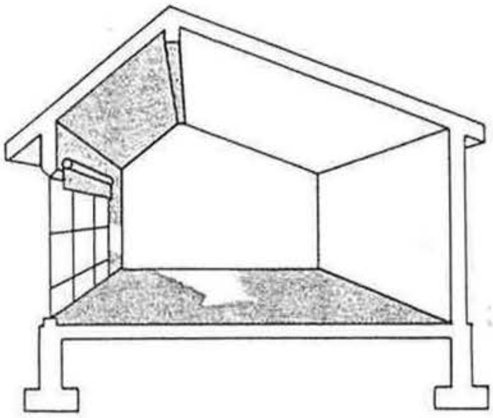
As part of good energy practice, passive solar technology can also make an important contribution to reducing the energy requirements of non-domestic buildings such as offices, schools and factories. For example, in commercial buildings lighting accounts for a major portion of the total energy requirement and significant opportunities exist for achieving savings through the optimum use of daylight.

Daylight is a greatly under-utilised energy

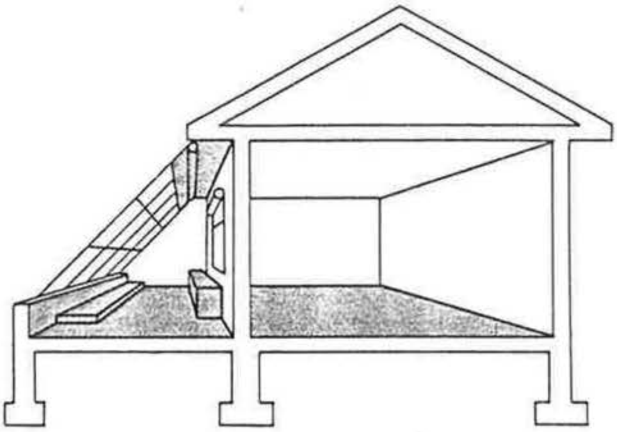
Active solar system at students hostel, Kirkcaldy, Scotland.

Schematic diagrams showing (left) direct gain and (right) attached sunspace features.

Direct gain



Attached sunspace



esource. Careful building design can produce omfortable levels of even interior lighting without glare, and yield significant savings in electricity consumption through the reduced need for artificial lighting and the consequent reduced need for cooling. *Perimeter daylighting* uses glass in various locations, such as normal windows and clerestories, to allow light to enter the perimeter rooms of a building. Baffles or ghtshelves then distribute the light evenly. *Core daylighting* systems use design features such as roof apertures, light wells and *atria* - glazed courtyards - to bring light to the interior of a building. Current research indicates that daylighting offers dramatic reductions in the energy costs in buildings with the high lighting nd cooling loads typical of commercial mises. Daylit spaces are popular with ilding occupants and daylighting systems an be fitted to existing buildings. On the other hand, bringing daylight into interior spaces still represents a difficult challenge. Designs involving atria, however, appear to produce many of the benefits of making the daylighting of deep spaces possible without posing extra windows or walls to the outer nosphere. At the same time, they provide ractive open areas for general use.

Active Solar Technology

Active solar systems involve the use of collectors to capture heat from the sun, and a heat transfer medium, such as water or oil circulated by means of a pump, to remove the heat and store it for later use. Active solar systems are used primarily for water heating and space heating and cooling. There are three basic types of collector. Flat plate collectors convert solar radiation to heat by the thermal interaction of an absorber with the incoming radiation: evacuated tube collectors function in the same way but use a vacuum to insulate the absorber face from convection and conduction losses: concentrating collectors use a reflective surface to direct incoming radiation within a wide angle of acceptance to a small receiver area.

Photovoltaics

Photovoltaic systems convert solar radiation to direct current electricity by the interaction of photons - tiny particles of ultraviolet, visible and near-infrared light - with the electrons in a semi-conductor device or cell. Solar cells can be made from a number of materials and fabricated in a variety of designs. Since 1980 single crystal silicon has been the most prevalent production material but amorphous and polycrystalline silicon are growing in use. Gallium arsenide is also being developed as a further alternative. A major photovoltaic industry has grown up worldwide. Originally sustained by the space industry, its major markets are now for consumer products, such as watches and calculators; power generation for remote locations; navigational aids; and water pumping and communication systems. Britain has a number of companies in this field and the Department of Trade and Industry has provided support for innovative projects designed to help British industry compete in export markets.

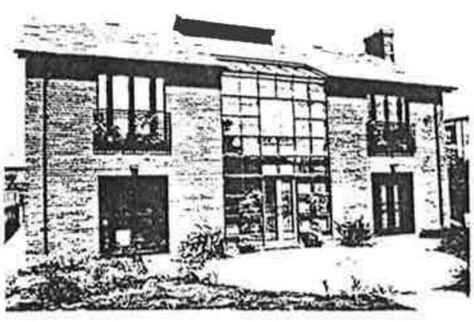
Solar Thermal Technology

This involves the use of collectors and concentrators to gather high temperature solar energy for use as industrial process heat, for irrigation pumping, for water desalination, and for electricity generation. Most systems operate by focusing sunlight to increase its energy density, usually by reflecting the direct rays of the sun on to a small target. A number of countries are involved in solar thermal R&D, notably the USA, Japan, Spain and France.

DEPARTMENT OF ENERGY PASSIVE SOLAR DESIGN PROGRAMME

The aim of the programme is to encourage the commercial integration of passive solar design into the UK energy economy by the mid-1990s. The intention is to determine, present and publicise the substantial benefits that derive from passive solar technology, not only in relation to energy performance but also in terms of the environmental and aesthetic qualities usually prevailing in passive solar buildings. The programme covers both the domestic and the non-domestic sectors and comprises four main activities – design studies, field studies, supporting R&D and information dissemination.

House at Milton Keynes designed by ECD Partnership incorporating solar pre-heating of ventilation air.

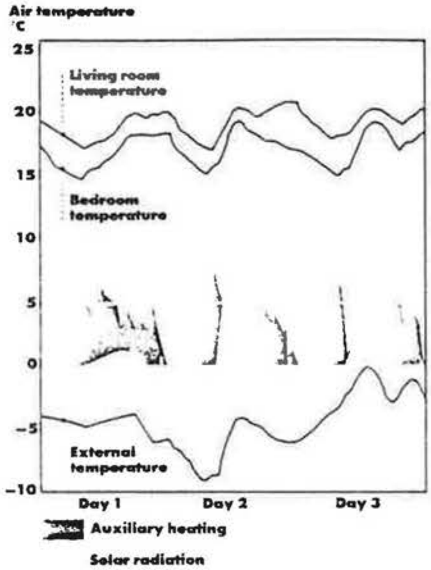


Design Studies

Design studies are central to the passive sola programme. Passive solar technology utilise patterns of complex interactions betwee factors as diverse as weather, glazing, incidenta heat gains and comfort standards. Such inter actions can only be studied realistically i the context of the total occupied building The design studies explore the scope for intro ducing passive solar technology, in conjun tion with the appropriate energy efficienc measures, into a wide range of building type both domestic and non-domestic. They hav four main objectives: to produce practica energy-efficient designs incorporating passiv solar features: to assess the performance an cost of buildings constructed to these design against conventional equivalents: to provide basis for live building projects which demo strate good passive solar and energy efficien design in practice - work that is linked wit relevant RD&D projects under the EEO programme: and to create a body of passiv solar design expertise within the buildin industry, its associated professions and amon its major clients. The studies are undertake in a cooperative manner with architect working within the discipline of repeate independent assessment of the designs' energ performance and predicted construction cos

HOUSING DESIGNS

The first design project, undertaken betwee 1979 and 1983, was an investigation of th opportunities for passive solar technology i existing houses. Based on a review of mo than 400 properties in Cambridge, the stu surveyed the form and fabric of existing housi stock to provide basic statistics. This w followed by a series of design exercises on th applicability of a range of passive solar an energy efficiency options in typical terrace semi-detached and detached houses, and by short field trial of the most promising optio Results showed that over 50 per cent of existi



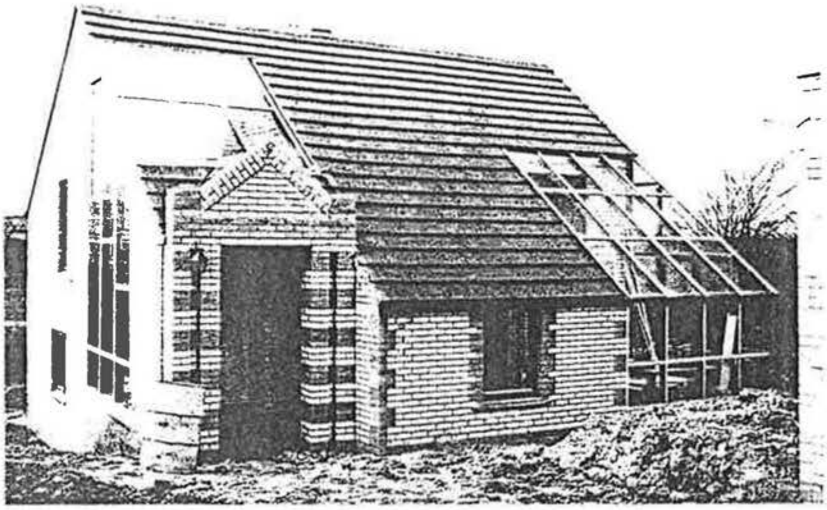
Graph showing actual gains from a passive solar designed house during a "cold spell".

houses could benefit from passive solar retrofit.

The second design project began in 1982 and involved 20 house design studies carried out by 17 architectural practices. The house types under consideration ranged from a small public sector terraced house to a four bedroom detached executive style private house. The project looked at both new-build and retrofit schemes. The studies were executed against reference designs based on the 1982 Building Regululations. Like the first design project, these 20 studies demonstrated clearly that passive solar design can bring about major energy savings cost-effectively in all but the smallest houses.

NON-DOMESTIC BUILDINGS

In 1984, design studies began on eight non-domestic building types - two offices, a hotel, a superstore, a light industrial building, a sports centre, a nurses' hostel, and a retrofit scheme at a system-built school. The performance and cost of each was compared with a conventional reference building. The combination of passive solar and energy efficiency features used in the designs has resulted in all eight being cheaper to heat and light than the reference designs. In five, savings would be 30 per cent or more; in three, the additional capital costs involved would be paid back in five to eight years.



South-east aspect of Cormack House. This is a development by Newton Architects, Ryton, Tyne and Wear. One of the Phase I design studies.

Field Studies

Practical field studies are essential to the credibility of any R&D programme on energy in buildings. They are especially valuable as a means of confirming the accuracy of model predictions and as sources of information about the way in which buildings are used. Analysis of measurements made in field studies provides a means of demonstrating the effectiveness of passive solar technology in real life situations.

The field studies in the passive solar programme have four main objectives: to provide firm evidence on the financial and non-financial benefits of passive solar design in a wide range of buildings: to increase general awareness of the design implications and visual impact of passive solar technology, its benefits and associated costs; to provide monitored feedback on performance and acceptability; and to provide a focus for the dissemination of information on the design and performance of passive solar buildings.

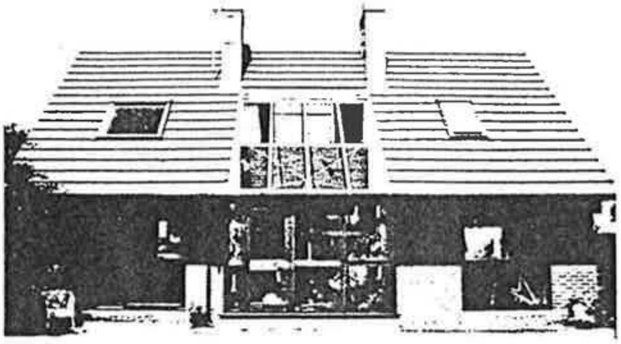
The earliest field studies were jointly funded by the Department and Pilkington Glass and carried out between 1978 and 1983 at Bebington on the Wirral. They involved nine small trombe wall houses and five conventional ones. The results showed convincingly that, although trombe walls can work in the UK climate, their capital cost is high and they are unlikely to prove economic.

Measurements on simpler, direct solar gain houses, carried out between 1979 and 1984 at the Pennylands and Linford estates at Milton Keynes, gave much more encouraging results. At Pennylands the overall performance of 177 houses was monitored, while at Linford a sample of eight houses was subjected to more detailed performance measurements. Together they demonstrated that even simple energy efficiency and passive solar heating measures can have a major effect on heating costs - reducing fuel bills by as much as 50 per cent compared with similar houses built to 1982 Building Regulations - without reducing comfort levels.

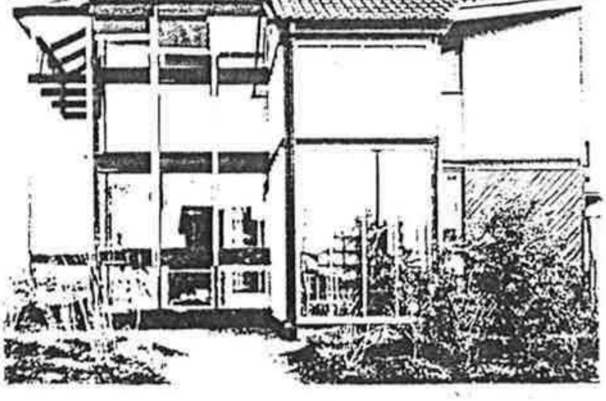
The first two sets of field studies, carried out on specific estates over a long period of time, gave detailed information about a limited range of designs. In 1986, a further programme of studies was initiated aimed at providing a more restricted range of data covering a wider range of passive solar features in a wider range of buildings types, including non-domestic buildings. The objective is to provide the construction industry and its clients with basic factual information on the performance and cost of passive solar technology in a form which is readily usable. The studies produce rounded assessments of energy performance, occupant satisfaction and capital costs. Considerable time and effort has been devoted to developing a methodology for this work that will maximise the value of the results to potential users and minimise uncertainties in the data. Eventually, a total of 40 buildings will be encompassed by the studies, including houses, schools, commercial buildings and factories.

EXAMPLES OF PASSIVE SOLAR BUILDING DESIGN IN BRITAIN

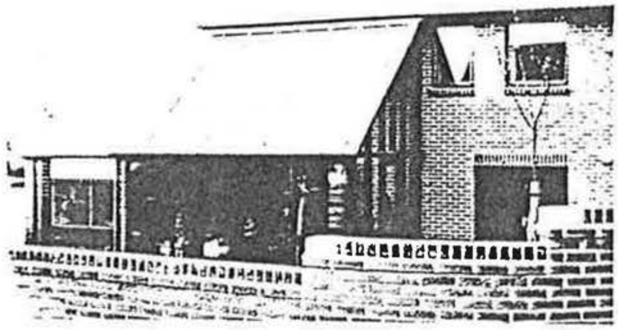
Pennylands passive solar estate design, at Milton Keynes.



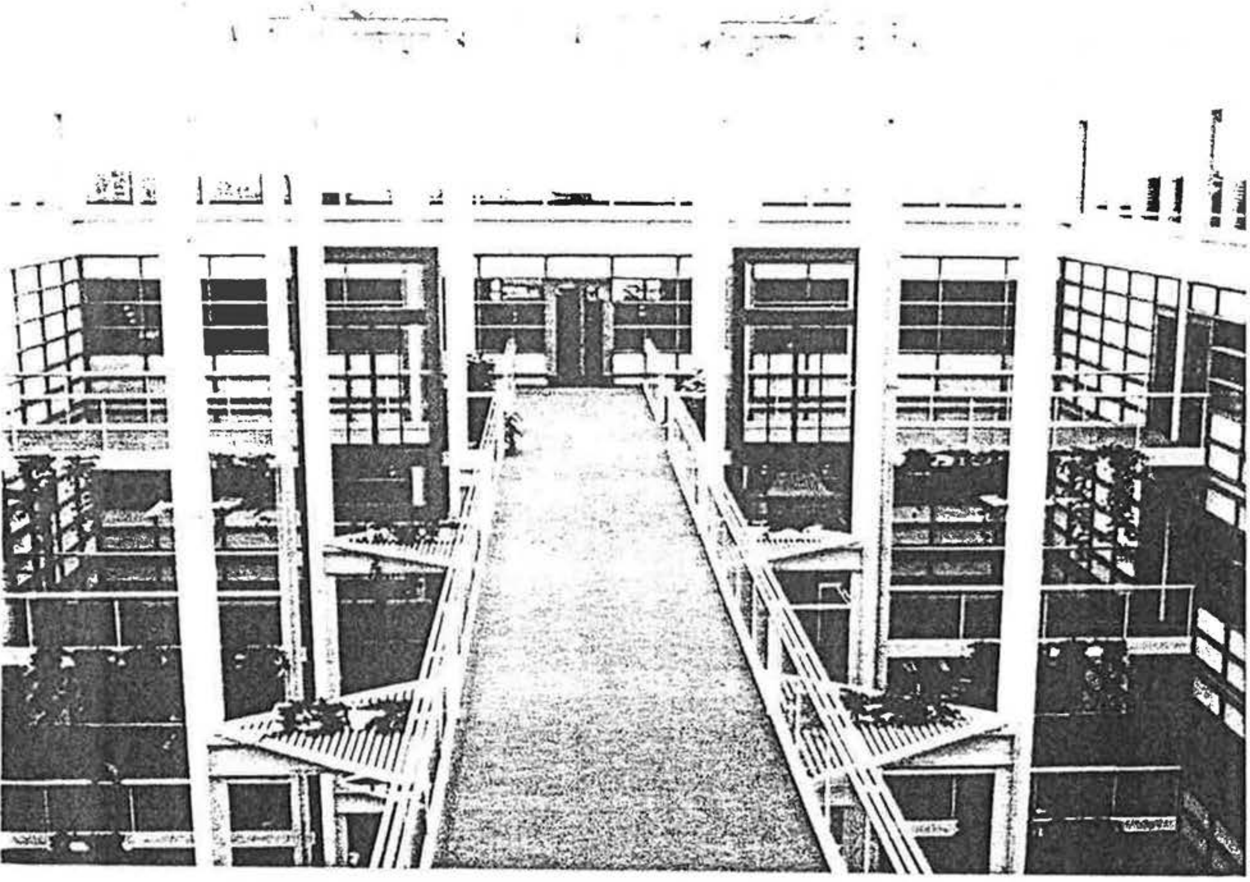
Solar Cottage, Warwickshire, one of the buildings in the passive solar field studies programme.



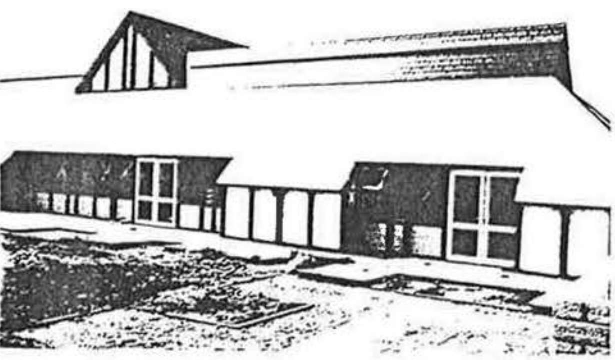
A passive solar designed house at 'Homeworld', Milton Keynes, showing a number of innovative passive solar features.



Private development at Willow Park, Lancashire incorporating passive solar design features and energy efficiency measures. The property was the winner of the 1986 NW Energy Group Award for energy efficient building.



Atrium at Wiggins Teape's headquarters at Basingstoke, designed for optimisation of daylighting and natural ventilation.



Passive solar design school at Netley, Hampshire, showing direct gain features.

DEPARTMENT OF ENERGY PASSIVE SOLAR DESIGN PROGRAMME

Supporting R&D

The Department of Energy is funding a range of supporting R&D studies to provide a solid technical basis for major projects, to improve design methods, to investigate new materials and techniques, and to understand market mechanisms, preferences and constraints.

PERFORMANCE ASSESSMENT

The passive solar programme makes extensive use of computer simulation to analyse and assess the thermal performance of building designs and specific design features. In recent years, some 40 per cent of the budget has been devoted to modelling and related activities and this represents a significant contribution to the international effort on passive solar modelling. The programme is now strongly directed towards the development of more reliable modelling systems and is taking account of market requirements and of related work in the private sector, the universities and the Building Research Establishment.

TEST CELLS

Computer modelling is useless without reliable data on the properties of materials and components. Many of these have been adequately characterised but there is still considerable uncertainty in a number of important areas, including the performance of windows. To reduce some of these uncertainties, test cells are being used to make empirical measurements of the properties of various building subsystems and components. The cells are also being used to measure the effects of net curtains and venetian blinds on solar gain through windows.

MATERIALS AND COMPONENTS

Proposals are being developed in association with Pilkington Glass for a series of shared-cost studies which would take the first steps towards launching a new generation of window materials around the year 2000. These studies aim to look at the potential technical benefits and at the market prospects for improved glazing materials, and to lay the foundations for commercial product development.

HOUSING ESTATE LAYOUT

A study has assessed the implications of estate layout for passive solar design. The results showed that, by taking care to achieve good orientation and to minimise overshading, it is possible to lay out houses containing passive design features at densities below 40 dwellings per hectare so that they achieve at least 80 per cent of their potential energy savings. If arranged conventionally, half these savings would be lost.

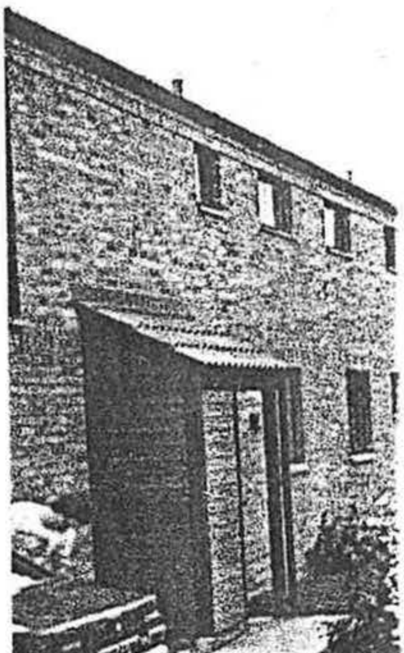
DAYLIGHTING

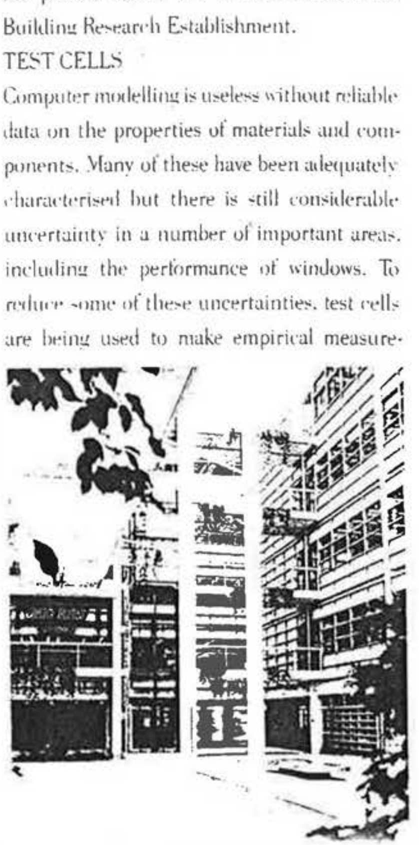
The Building Research Establishment has carried out a study of the potential for the increased use of daylighting in non-domestic buildings. It concluded that energy equivalent to around one million tonnes of coal a year could be being saved by the year 2020 in commercial, industrial and institutional buildings through a combination of architectural measures to make more daylight available and improved lighting controls. However, more research is required into the subjective quality of daylight and into techniques for using it. And design guidelines for the construction industry and its clients will be needed if daylighting's full potential is to tapped.

MARKET STUDIES

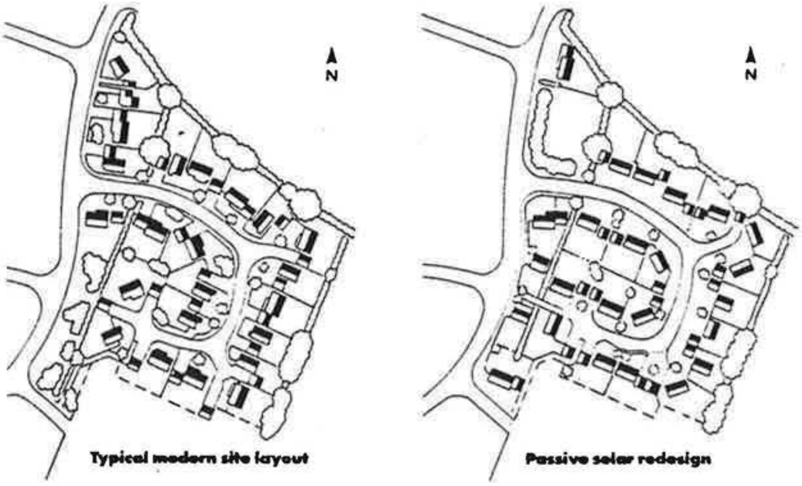
Despite the many different technical and architectural considerations involved in passive solar design, it should never be forgotten that buildings are for people and that the development of passive solar technology ultimately depends on its public acceptability. The London Business School has now carried out two studies of the private housing market with particular regard to the attitudes of house buyers and decision-makers in the construction industry towards energy efficiency and passive solar design.

The key conclusions about purchasers were that they are prepared to pay a modest premium for energy efficiency and that their reactions to individual designs depend much more on appearance and expectations about amenity than on cost-effectiveness. Responses to interviews and a large survey of buyer





'Gateway Two', Wiggins Teape, Basingstoke, designed with atrium to promote natural ventilation and daylighting of the building thus cutting construction and energy costs.



Comparison of conventional housing estate layout with the solar designed, minimum shadowing Pennylands estate at Milton Keynes.

View of Pennylands estate, Milton Keynes, showing the variation in glazed area between northern and southern aspects of the houses.

however, showed that good passive design can be at least as attractive as conventional housing. This view was reinforced by the generally favourable public reaction to the passive solar houses in the Energy World exhibition mounted at Milton Keynes in autumn 1986.

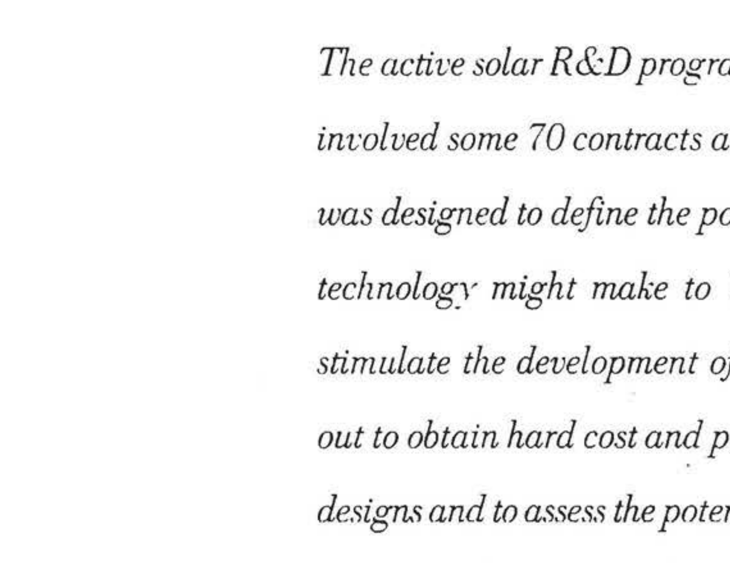
Developers are the most influential group on the supply side, and the main obstacle to an improvement in the energy efficiency of new housing appears to lie in a lack of belief, or simply a lack of confidence, on their part that buyers are prepared to pay a sufficient premium to outweigh any extra costs involved in passive solar features. There still exists the perception that energy efficient houses are less marketable, more expensive to build, and are accompanied by adverse side effects. And many builders have little confidence that their workforce can cope with the detailing necessary for good energy efficient design. These are all barriers to the adoption of passive solar design which the Department's renewable energy and energy efficiency R&D programmes are tackling vigorously.

Information Dissemination

If passive solar technology and energy efficiency good practice are to make the contribution to Britain's energy economy that they should, the construction industry, its clients and the general public will need to be convinced that the benefits are real, that technical risks are minimal and that associated costs are well established. A major component of the passive solar programme, therefore, is the dissemination of results and information arising from the programme, and from other relevant work around the world, in forms tailored to the requirements of the various audiences. Publications range from general brochures to stimulate initial interest through to articles for professional journals, detailed research reports and design handbooks for practice in the field. Specific teaching materials are being developed for use in undergraduate and professional courses. And consideration is being given to the production of expert systems for micro-computer and interactive video use, building on projects supported by the EEO.

DEPARTMENT OF ENERGY ACTIVE SOLAR HEATING PROGRAMME

The active solar R&D programme ran from 1977 to 1984, involved some 70 contracts and cost almost £4 million. It was designed to define the potential contribution that this technology might make to UK energy supplies and to stimulate the development of cost-effective systems. It set out to obtain hard cost and performance data, to optimise designs and to assess the potential for further improvements in cost, performance and market appeal.



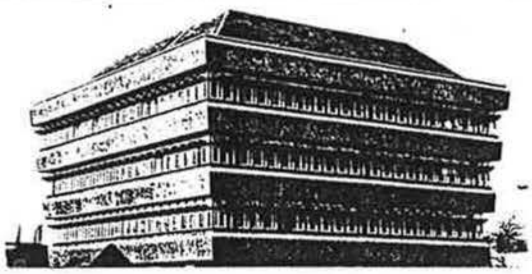
A conventionally designed solar water heating system retrofitted in a dairy parlour at Seale-Hayne College, Devon.

The programme concentrated on domestic water and space heating but some projects looked at other applications in institutional buildings, such as schools and hospitals. A wide range of activities was covered, including component and system development, laboratory testing, field trials and modelling studies. There was a deliberate policy of collaboration with industry where possible both to maintain commercial realism and to encourage early exploitation of promising developments.

The programme assisted the solar heating industry in a number of areas. It helped in the development of valid testing procedures. It provided data on the mounting of collectors on roofs which have been incorporated in the appropriate Codes of Practice of the British Standards Institution. As a result of the programme, the sensitivity of system performance to key design parameters is now understood, the relative merits of various design options are better appreciated and the main design pathways and constraints have been identified. Jointly-funded projects to develop components have helped industry design and build new solar-related products. And field trials and specially commissioned studies have produced data on the future development of the active solar market in Britain.

Largely as a result of the programme, it is now possible to design and install active solar heating and hot water systems that are reliable, durable, and capable of performing close to expectations. With few exceptions, however, the costs of the installations are high compared with the financial returns from fuel savings. As a result, the programme concluded that active solar space heating in Britain could only be cost-effective if fuel prices rose to extremely high levels. Primarily this is because of the mismatch between the time when the heat is available and when it is needed, and because of the complexity of the systems required to utilise the heat. As far as solar water heating is concerned, the economics do not look favourable for a typical domestic installation. On the other hand, the technology could be attractive in certain limited circumstances, and there will continue to be a market for solar heating for swimming pools and for specialised applications in industry, commerce and agriculture where large quantities of tepid water are required.

No new technical approaches have arisen to justify further Department of Energy support of active solar technology in the UK. However work continues in other countries with more favourable climates, particularly on collector technology, and the Department of Energy is keeping a close watch on these developments.



Headquarters, South Staffordshire Water Company, Walsall, an office building which makes extensive use of passive solar design techniques.

This building is the subject of study under the US/UK bilateral agreement.

INTERNATIONAL COLLABORATION

ithin the renewable energy field, solar energy is one of he most active areas for international collaboration on esearch and development – mainly because it is a resource ommon to every country in the world. Britain is involved n a number of international collaborative projects on assive solar design. It also maintains international conections with work on active solar heating and on photooltaic cell and system development, areas where British anufacturing industry could develop export markets.

Britain collaborates internationally on passive solar R&D principally through the Commission of the European Communities (CEC), the International Energy Agency (IEA) and under a bilateral agreement with the United States.

The CEC has identified the extent of the solar resource in Western Europe and presented its findings in a Solar Energy Atlas. The work has shown that the resource in certain localised regions varies considerably from the general pattern. A database is being developed on the effects of microclimate on solar radiation availability. Tests will be conducted at eight selected sites to determine how microclimatic effects can be incorporated in the design of solar installations, including passive solar buildings. One test site is located on the Firth of Forth in Scotland, where the work will be carried out by the Scottish Institute of Agricultural Engineering, Edinburgh. PASSYS, a European concerted action programme in the field of passive solar component and system testing, started in April 1986 and is due to run until March 1989. Its aims are to validate and improve thermal simulation: to develop and test simplified design tools: to develop simple and reliable test procedures: and to use these procedures to acquire performance data which can be applied to practical installations. The CEC also provides support for passive solar building projects under its Energy Demonstration Programme, which has awarded grants to a number of British projects.

International solar energy R&D projects are also being carried out under the IEA's Solar Heating and Cooling Programme. This is a cooperative programme, with each participant providing its own funding, and is divided into 11 tasks - two of which are devoted to passive solar technology. Britain is taking part in both of these, with funding support from the Department of Energy. Task VIII deals with domestic buildings and aims to gain an improved understanding of the design and performance of new low energy housing containing passive solar features. Task XI is concerned with non-residential buildings. Its objectives are to accelerate the development and use of innovative passive solar features by providing case studies on existing buildings in the participating countries. Under the IEA's Building and Community Systems R&D Programme, collaborative research and development is being carried out on relevant energy efficiency projects associated with buildings.

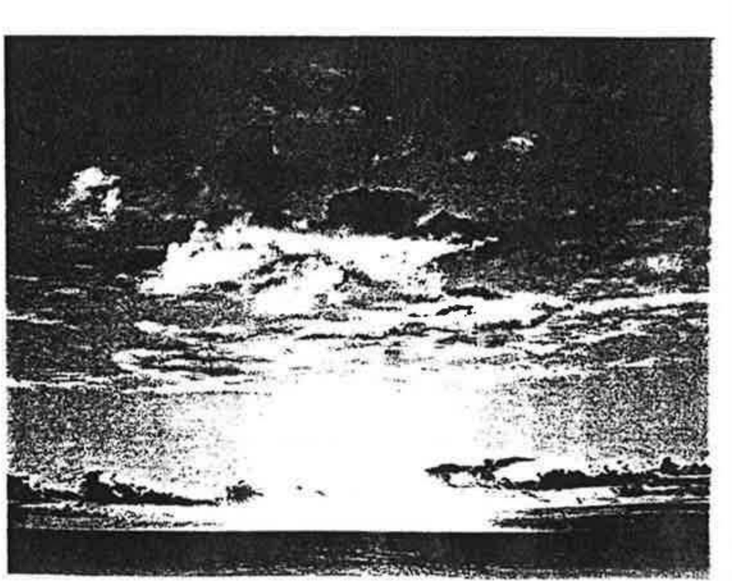
Under a Memorandum of Understanding, Britain and the USA are exchanging information on passive solar technology and developing cooperative projects. These include work being carried out by Pilkington Glass, Libbey Owens Ford and the Lawrence Berkeley Laboratories in the USA to develop improved glazing materials which could increase the potential for passive solar design still further.

PLANNING FOR THE FUTURE

Over the past few years increasing emphasis has been placed on technology transfer activities which will assist the adoption of passive solar technology in Britain. The point has been reached where this shift in emphasis needs to be accelerated so that passive solar design and energy efficiency techniques become widely regarded as essential characteristics of good building design and practice. The Department of Energy is therefore intensifying its programme of design studies, field studies and supporting research in order to resolve remaining uncertainties and is increasing its effort on promotion and technology transfer to stimulate market interest.

Once the most appropriate technology transfer mechanisms have been evaluated, th programme will engage in a major exercise t bring its findings to the attention of the co struction industry - in particular developer architects and major clients - and to th general public. Its information disseminatio activities will be expanded to provide not onl hard data but also practical guidelines on th use of materials and design configuration Consideration is also being given to a numbe of innovative technology transfer technique which would further promote the take-up o passive solar technology.

Passive solar design, in conjunction wit energy efficiency, is economically attracti now. Deployed on a commercial scale, it ha immense benefits to offer Britain and all wh use buildings - and that means everyone i the country.



WHERE TO FIND OUT MORE

For further information about the Department of Energy's Solar Energy R&D Programme, and for more details about other technologies in the Department's Renewable Energy Research and Development Programmes, please contact:

Renewable Energy Enquiries Bureau
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For further information about the EEO's R&D programmes on energy efficiency in buildings and on buildings generally, please contact:

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