GREEN POWER

CONTROLLING PASSIVE SOLAR THERMAL GAINS

EXTENDED RENEWABLE ENERGY CASE STUDY

INTRODUCTION

Passive solar energy is simply the energy from the sun that is absorbed by buildings. All buildings receive passive solar energy in two main forms: thermal gain and daylight gain. By regulating these gains, energy demands can be reduced and comfort levels increased.

The easiest way to control thermal gains is by regulating the size and orientation of windows. Owing to the angle of the sun in the UK, the highest year-round solar thermal gains are gathered on south-facing façades. Therefore, to increase thermal gains, large windows are installed facing south. Conversely, thermal gains can be reduced by orientating large light-gathering windows towards the north or east and installing small south-facing windows, by shading south-facing windows or by coating windows with reflective film.

Installing large south-facing windows to take advantage of solar thermal gains can mean that heating bills for the whole building are significantly reduced, with the additional benefit of increased levels of natural light. However, to obtain best results from passive solar thermal, the technology is best installed as a new-build project, or as part of a major refurbishment. This is because design considerations must be made as to how to channel the warmth around the building and how to control thermal gains when a desired temperature is reached.

Similarly, if the design and occupation type are likely to lead to high cooling requirements, it is most cost-effective to consider measures to reduce thermal gains as part of the overall building management scheme during the initial design phase. This is particularly important because standard air conditioning plant, as well as being expensive to install, are very energy-intensive. It costs several times as much to cool the air in a room by 1°C as to heat it by the same amount. Because of the high costs of cooling, good payback times can therefore still be achieved with retro-fitted technologies. Even in a well-designed building, changing occupation patterns can cause some rooms to need additional cooling mechanisms. For example, most office buildings have far more electrical equipment now (all producing heat) than 10 or 15 years ago, so many building managers are looking at installing air-conditioning. As this is so expensive, other options should be investigated before its installation.

DTI New & Renewable Energy Programme

dti
Department of Trade and Industry

First issued May 2000

The projects described in this publication are current examples of operating renewable energy schemes, but may not represent best practice in all respects.

REDUCING SOLAR GAINS TO A COMPUTER ROOM

The New Walk Centre

This case study aims to show how two very different buildings have managed to control their solar thermal gains, through different approaches and applications of technology.

LOCATION

Main computer room in Leicester City Council's New Walk Centre offices (B Block), Leicester.

BACKGROUND

The New Walk Centre contains the main council offices in Leicester. It is a very striking building, located in the city centre, made up of two large tower blocks (one of 8 storeys, one of 13). However, both buildings share many of the flaws of other 1960s architecture, in that they were built largely with aesthetics in mind, without enough thought for functionality and user comfort. Over 60% of the external fabric of the New Walk Centre is glass. This leads to two main problems: firstly the single-glazed windows lose large amounts of heat in the winter, and secondly the south- and west-facing windows experience excessive solar gains in the summer. The second of these issues is more important, borne out by the fact that the total gas bill for the two buildings in 1998 was £25,000, whereas the electricity bill was £130,000. Although this electricity bill includes the costs of lighting and office equipment, it has been calculated by the Council's Energy Team that it costs more to keep the buildings cool in summer than to keep them warm in winter.

The Roots of Leicester's Sustainable Commitment

Leicester City Council is the first unitary local authority in the UK to have achieved full Environmental Management Audit Scheme (EMAS) certification. This has been made possible due to a comprehensive and holistic approach to environmental policy. Energy awareness has been central to Leicester's environmental policy since the municipality of Leicester was granted the status of first "environment city" in 1990. This commitment to energy has been reflected since then by the continuing publication of reports and targets, together with the Council's status as one of the first Energy Efficiency Advice Centres (EEACs) to be launched in the UK (in 1993). This record is set to continue and expand as the Council bids for European Objective II funding to incorporate new and renewable energy into homes, schools and businesses in the area.

One of the key commitments Leicester gave when bidding to become firsr "environment city" was the reduction of energy use within the city to 50% of 1990 levels by 2025. This target is enhanced by the vision of meeting 20% of the city's energy needs from renewable sources by 2020. To help to meet these challenging targets, the City Council is actively promoting energy efficiency and renewable energy through the EEAC, housing associations and Article 10 regeneration projects, and, most importantly, is taking the lead itself, through the implementation of energy efficiency measures and the integration of renewable energy into council buildings.

The Council's commitment to sustainable energy use starts at the very top level, with the Chief Executive making a Corporate Commitment in 1992 to embed consideration of energy consumption into all decision-making. This means that all equipment now purchased must conform to a certain standard of energy efficiency; all new-build projects must actively seek to incorporate new and renewable energy and energy-efficient technologies. All the monitoring and purchasing of energy is now handled centrally at the Energy Centre, so that best value can be obtained and any anomalies can be spotted and rectified easily. It is this commitment at all levels that has allowed Leicester to set such ambitious energy targets.

PLANNING

As part of Leicester City Council's commitment to the reduction of energy use (see box above) an internal study was carried out in 1993 by the Council's Energy Team to assess the potential for controlling passive solar gains in the New Walk Centre buildings. The rationale was that, by controlling solar gains, the need for winter heating and summer air-conditioning would be reduced, which in turn would lead to energy and hence financial savings. An added advantage is the increased comfort, and hence morale and productivity, of staff. However, this is very difficult to quantify in financial terms due to its complexity.

The study concluded that the south- and west-facing sides of both buildings – especially the areas above floor 4 – were subject to excess solar gains, whereas all windows lost large amounts of heat in the winter. The report went on to identify options for reducing energy wastage. Firstly, all rooms that suffer from excess heating in the summer could be treated to reduce these gains, by installing either solar shades or solar film. Either of these options would solve the overheating problem, but both share the disadvantage of being extremely capital-intensive. Additionally, planning permission would have to be granted to install the solar shades, as this would alter the external appearance of the building. The solar film was identified as the better option as it would have the advantage of reducing through-window heat loss by up to about 30% (about the same as for double glazing). However, to treat all windows with solar film would have cost £82,600 and, even with a simple payback of 4 years, this was considered to be too capital-intensive to implement.

The second option was to treat only the rooms that suffer the most from the more excessive thermal gains. By doing this, the

Installation of film

SOLAR FILM

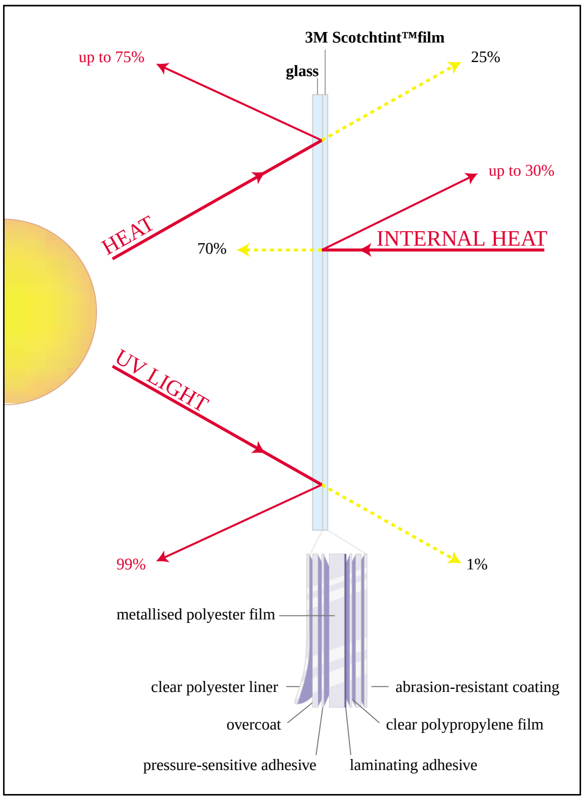
Solar film is a very simple but effective technology that comes in a range of different specifications. It consists of bonded sheets of metallised polyester, polypropylene and adhesives, and is simply stuck directly onto the surface of the window. It then acts like a mirror to reflect up to 75% of the infra-red radiation (the heating wavelength) away from the window, hence reducing the internal solar thermal gain. It can also cut out 99% of the UV light, which causes fading of furnishings and fittings, and some types also reflect back internal heat, cutting through-window losses by up to 30%. Because there is such a variety of film it is possible to specify solar film to suit individual requirements. Therefore, for north-facing windows, it is best to use film with maximum internal retention qualities, with external reflection as a secondary requirement, as the windows do not receive excessive summer sun. For south-facing windows, the film needs to have high reflective qualities to cut down the excessive summer gains, yet needs to have relatively high levels of internal retention to avoid winter heat losses.

The use of the heavier solar films can cut down on internal light gain, so they must be carefully applied to ensure that thermal savings are not offset by increased spend on lighting. Most, however, have very little effect on internal light levels, although they can give the exterior a mirror-like appearance.

potential energy savings of the installation can be maximised. A number of rooms with higher than average temperatures were considered, including the canteen, the print room and the main computer room in B Block. The computer room was selected for an experimental application of solar film, for two main reasons. Firstly, the growing computer network had resulted in a large number of new servers being purchased, hence a higher output of heat. Therefore additional air-conditioning was being considered as an option to provide the extra cooling, at a cost running into thousands of pounds. Secondly, the heat input from the servers meant that solar film was the right technology as cooling was needed on a year-round basis.

TECHNOLOGY

In 1994 3M Scotchtint solar film was applied to the 57 south-east-facing windows in the B Block computer suite. The film used is treated on one side only, to minimise the incoming solar radiation without much altering the outgoing heat transfer. This type of film was chosen for the computer suite due to the generation of excessive heat all year round by the computers. The installation of the film is a quick and simple process, although some upheaval is necessary. The glass must be thoroughly cleaned, then the film is floated onto the glass and carefully and thoroughly squeegeed out to ensure a complete bond to the glass. The film is then allowed to dry out or cure over the next two or three weeks depending on the external and internal temperatures. Before the process of cleaning can begin, the whole area must be cleared, including moving any furniture away from the windows, clearing the window-ledges and removing the blinds. However, this normally leads to minimal disruption, and by outlining the comfort benefits to the staff it is easy to overcome any resistance.



COSTS AND SAVINGS

The total cost of installing solar film on the 57 windows in the computer suite was £1425 (£25 per window) which was financed by the IT department. The cost of running the 20 existing fan-coil chiller units (rated at 1.5kW) at a cost of 4.88p/kWh is £1.50 per hour. These need to run for an average of 17 hours per day for 150 days per year, so the total cooling cost for the computer suite alone is £3825. Monitoring of the room since the solar film was installed has shown that the air-conditioning is running with a 15% load reduction, delivering annual savings of £573. As the initial outlay was only £1425, this represents a simple payback of under 2.5 years, with further savings being made on servicing requirements and reduced mechanical breakdowns. Additionally, since the solar film has been installed, the air-conditioning has not needed to be upgraded, even though the number of computers in the room has increased dramatically.

BENEFITS OF SOLAR FILM FOR COOLING

- **Reduced passive thermal gain in summer, therefore reduced air-conditioning requirements.**
- **Annual savings of £573, giving the project a 2.5 year payback.**
- **Reduced solar glare, resulting in a better working environment.**
- **Improved safety, as glass will be shatter-proof.**

CONTROLLING SOLAR GAIN IN A CORRIDOR, BEACON ENERGY

LOCATION

Whittle Hill Farm Buildings, Nanpantan, Leicestershire.

BACKGROUND

The Whittle Hill buildings comprise 105m^2 of obsolete farm buildings that have been converted to offices by Professor Tony Marmont to accommodate MRETT (Midlands Renewable Energy Technology Transfer) and Beacon Energy (a "green electricity" producer which supplies electricity to Leicester City Council). The buildings have been designed to be as ecologically sound as possible, starting with the decision to re-use existing building stock, therefore reducing the energy requirements of construction. This ecological building theme is continued through the use of high levels of insulation, purifying rainwater for drinking, the use of waterless urinals and the incorporation of a number of renewable energy projects into the building fabric. MRETT has close links with Nottingham, Loughborough and De Montfort Universities so the MRETT building also serves as a test bed for many new technologies. This has led to the commercial development of a number of new technologies.

View of the corridor

CONCEPT

One of the features of the MRETT building is a 27m-long right-angled corridor, running along the south and west faces of the main buildings, which connects up the individual offices. In addition to access, this corridor serves to regulate the temperature of the whole building. The corridor is lined with 1.5m-high double-glazed windows, with 12m facing south and 15m facing west. The sun heats the stone walls and floor of the passageway. Warm air is drawn from this area to feed a pulse jet furnace which circulates warm air into each room via under-floor ducts. The air exits each room via overhead outlets back into the solar passageway for re-heating by the sun and return to the furnace. Good design has therefore meant that there is very little need for electrical input.

REFINEMENT

Although the system works very well for most of the year, in the summer months too much heat is gained by the solar corridor. To avoid this, two measures were introduced. Firstly, solar shades were installed above the windows, designed to have just two settings for simplicity: open and shut (or winter and summer). The concept is very simple: in summer the sun is high in the sky for much of the day, so by closing the slats, the entire window will be shaded without being covered over. Therefore, direct solar thermal gain will be stopped, yet the windows will still be able to gather large amounts of natural light. Conversely, in winter the sun remains very low in the sky. At this time the open slats are orientated to run parallel to the sun's angle of incidence and so let in maximum light. Therefore, the slats allow in almost unchanged levels of light and heat when open in the winter.

The second passive cooling technique makes use of the supply and exhaust fans already installed to force draught air through the ducting at night, to take the additional heat out of the building - especially the stonework of the corridor. This worked successfully in 1995, when the internal temperature remained constant at around 20-22°C although the external ambient temperature was often over 30°C.

COSTS AND SAVINGS

It is very difficult to say how much the majority of this project cost, for a number of reasons. Firstly, the corridor was constructed during the building renovation so the cost has been somewhat absorbed into the general price. Secondly, the corridor has been designed primarily as a functional access corridor, with the solar thermal system added as a complementary feature. Therefore, to try to calculate paybacks for the corridor would be as irrational as trying to calculate a payback period for a front door! However, the only real costs to be considered for the payback are the costs of additional and upgraded materials to make the passive heating system work. The total cost for the corridor was approximately £15,000, of which the cost of upgrading the windows from single to double glazing and installing insulation to give the walls a u-value of 0.35 and the floors 0.40 amounted to £900 - no more than 6% of the total costs.

Similarly, savings are hard to calculate for any one feature of the Whittle Hill Buildings, but it is certain that the passive solar heating will have contributed to the building's very low energy use. The buildings have a power consumption of just 150kW per square metre, compared with the average for English office buildings of 400-500kW.

It is easier to quantify the costs of installing the retro-fit cooling feature of the solar shades and the fans. The fans were already installed, so the new use simply extended their operational hours, for no additional installation cost. During summer operation, these draw a total of 4.68kW of electricity between 00:30 and 07:00, at a rate of 8p per kWh (or free if Beacon Energy's turbines are working), giving an average daily cost of 37.5 pence. The 27m of solar shades cost approximately £6400 to design and install. These are hand-operated and therefore draw no power, with the simple design meaning that there have been no maintenance costs to date, so all savings go straight to the bottom line.

Another way of justifying costs would be to say that the costs of any energy features in the corridor area could be offset against the fact that this was a refurbishment as opposed to new-build. The embedded value of the existing resources would compensate for any additional costs incurred in the use of renewable energy.

Also, it is likely that, if passive heating and cooling techniques had not been utilised in this project, other conventional, energy-intensive systems would have been used. These would have brought with them capital which would have been on a par with the passive system and revenue costs which would have been much larger.

BENEFITS OF CONTROLLING SOLAR GAIN

- **Passive solar heating and cooling minimise the costs of heating and cooling, in both summer and winter.**
- **Total temperature heating/cooling costs are now much less per year compared with the average for a similar building.**
- **Integration into major refurbishment of old buildings means that the costs of "good design" are negligible.**
- **Re-use of existing building stock reduces resource and energy requirements of new-build.**
- **"Dead" corridor space becomes a functioning part of the whole building.**

SUMMARY AND RECOMMENDATIONS

For both the above examples, the techniques used to achieve the required temperature control have been carefully chosen for the specific situation. The use of one-way solar film is a cost-effective way to respond to a change in the New Walk Centre's occupation pattern, whereas the passive cooling and heating at Whittle Hill was made possible by the major refurbishment of the building. Unfortunately, it is very hard to prescribe a certain course of action for all buildings as their size, age, orientation and occupation pattern (to name but a few) affect the choice of methods available. However, the list below outlines the best general approach to optimising passive energy use in a number of different situations.

1. New building - drawing-board stage

A situation whereby a building is to be designed from scratch gives the greatest freedom to achieve cost-effective solutions. There are many options to be considered, including measures to reduce heating and cooling bills through passive cooling/heating and through good air circulation, measures to cut lighting bills by channelling light to all parts of the building and good design to minimise heat loss in winter. However, the best general approach is to carefully consider *exactly* how the building will be used for both the present and the future (including numbers of people, levels of equipment and where activity will be concentrated), then seek professional advice. Free and impartial advice is available from the DETR's Energy Efficiency Best Practice Programme (Design Advice - Towards Greener Buildings) on Tel: 01923 664258. Good initial design of a building will allow the building to operate efficiently with reduced energy consumption and improved comfort for the occupants. What is more, simple good design that takes advantage of passive energy is often no more expensive than conventional design, so the building will make financial savings as soon as occupation commences.

2. New build of an existing design

Even if a building has already been designed, it is still possible to make improvements to the energy use and comfort levels by choosing technologies that will take advantage of passive energy. The best option is to take the finished design particulars to a professional green building architect: again the Energy Efficiency Best Practice Programme (Design Advice - Towards Greener Buildings) on Tel: 01923 664258 will be able to help. The Programme will be able use the designs plus information on the occupation patterns to highlight areas that may experience problems of cold or excessive heat or lighting problems. By simply specifying windows treated to prevent excessive solar gain, or with low-emissivity glass to reduce heat loss, localised temperature problems can be overcome for very little cost. Similarly, light pipes can channel natural light to dark areas, with much of their cost being absorbed into the cost of the building.

3. Major refurbishment

Where a major refurbishment is to take place, it is important to consider past problem areas and to combine that knowledge with the new design. In the Whittle Hill example, there was complete freedom over the refurbishment of the building which allowed passive energy to be used for both heating and cooling of the building. The level of input at the design stage will dictate how much influence over passive energy use you have, but always remember to take advantage of the Energy Efficiency Best Practice Programme (Design Advice - Towards Greener Buildings) on Tel: 01923 664258. Again, because any improvements will be made as part of a major refit and are likely to be simply upgrades, the additional cost will be minimal.

4. Minor refurbishment/Change of occupation

These have the major benefits of responding to existing problems within a building, so the solutions can be very specifically designed. However, the options are generally limited to controlling thermal gain from windows or (depending on the building size) improving air circulation within the building. If a minor refurbishment involves changing windows, always consider the use of ones treated to prevent excessive solar gain, or low-emissivity glass to reduce heat loss, depending on the local heating or cooling needs. It is rare for the costs of any temperature regulation works to be absorbed into the cost of minor refurbishments, so the changes are best viewed as investments with payback periods. Always remember to calculate these paybacks from the *additional* cost of the upgraded technology, *not* the entire cost of the project!

In all cases, in addition to considering the simple paybacks gained from energy savings, think about the benefits to staff that working in a comfortable environment will bring. Although this is very hard to express in financial terms, it is often more valuable than the energy savings.

Close up of the solar shades above the corridor windows

FURTHER INFORMATION

For information on this project, and others in Leicester, please contact:

Leicester Energy Agency
2-4 Market Place South
Leicester
LE1 5HB
Tel: 0116 2995133
Fax: 0116 2995137
e-mail: Donlack@energy-advice.co.uk
Web: www.energy-advice.co.uk

For information on the DTI's New & Renewable Energy Programme please contact:

New & Renewable Energy Enquiries Bureau
ETSU
Harwell
Didcot
Oxfordshire
OX11 0QJ
Tel: 01235 432450
Fax: 01235 433066
e-mail: NRE-enquiries@aeat.co.uk
Web: www.dti.gov.uk/renewable/index.html

NEW REVIEW

The DTI's quarterly new & renewable energy newsletter is available on the Internet at www.dti.gov.uk/NewReview/