SKYLIGHTS SAVE ENERGY!

By Bill Hawker

New research proves conclusively that skylights save energy. A well-designed building with a good spread of natural light will benefit from passive solar gain and a reduced requirement for artificial light. The combination of these factors means that including skylights can offer a dramatic reduction in a building's total energy consumption and the emissions of CO_2 associated with this energy use. A naturally-lit interior will save money, provide a more pleasant environment where people want to spend time, and contribute to the reduction of CO_2 emissions.

The National Association of Rooflight Manufacturers (NARM) commissioned the Institute of Energy & Sustainable Development at Leicester's De Montfort University to undertake a study to investigate the effect skylights have on the annual CO_2 emissions which result from the use of energy needed to operate a building.

Overall Impact

There was a widely held view that while skylights are an excellent way of bringing the many benefits of natural light into a building, their poorer insulation value allows more heat to escape than the rest of the roof structure, increasing the running costs of the building. The research by the Institute of Energy & Sustainable Development confirms that this is wrong: installing an appropriate level of skylighting can reduce overall energy consumption.

In relation to skylights, heating is only one element of the energy equation. The primary reason for including skylights is to provide a bright, naturally-lit interior and reduce the requirement for artificial lighting. Daylight has many advantages over artificial light – not least the fact that it's a completely free, unlimited natural resource. While artificial light is essential today, providing it uses a lot of energy, so reducing the requirement will cut CO_2 emissions dramatically.

Assessing the overall impact of skylights and glazing on the energy efficiency of a building is a complex task. Consideration must be given to the glazing's inferior insu-

There was a widely held view that while skylights are an excellent way of bringing the many benefits of natural light into a building, their poorer insulation value allowed more heat to escape than the rest of the roof structure, increasing the running costs of the building. This is wrong, according to new research.

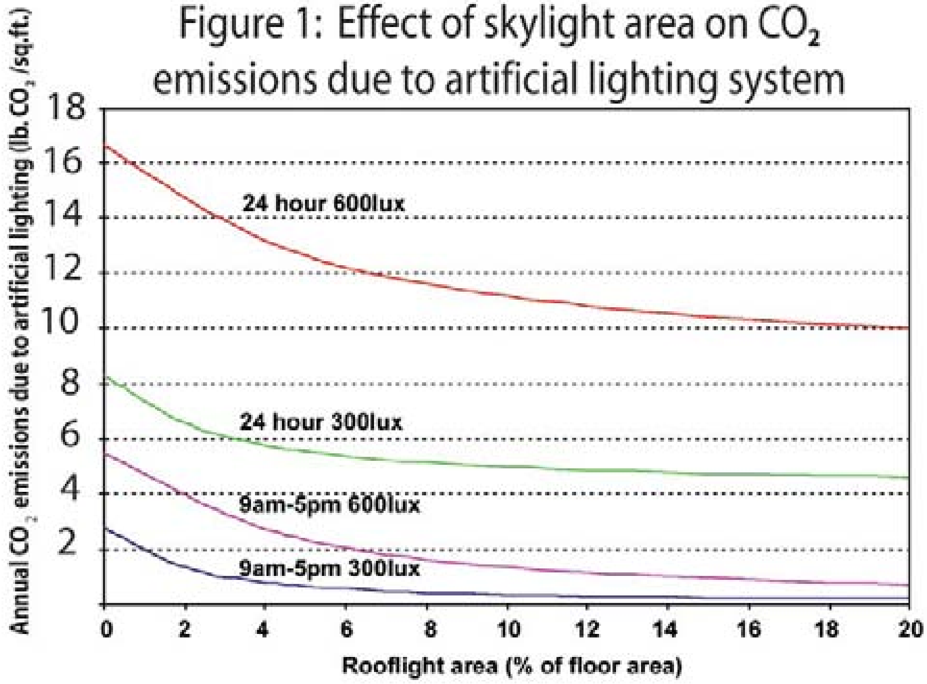


Figure 1: Effect of skylight area on CO_2 emissions due to artificial lighting system

lation value compared with the surrounding cladding balanced against the passive solar gain through the glazing, and the amount of energy needed to artificially light the building whenever there is insufficient natural light. The amount of energy required to provide artificial light is much greater than the energy needed to compensate for loss of heat through the skylight.

The research considered the thermal effects (and energy used by the heating system) and the illumination effects (and energy used by the lighting system) separately, then quantified each of these effects to establish the overall effect of skylight area on total energy use and the equivalent CO_2 emissions.

Thermal and lighting analysis was undertaken using state-of-the-art software to process actual weather data for a test reference year at a number of locations around the country. It analyzed the heat flow and illuminance through an entire roof for skylights covering between 0 and 20% of the roof area.

Energy Plus software was used to establish the effect of skylight area on heat flow through the whole roof. This complex thermal analysis took into account the different insulation values of the roof and skylights, differing internal and external temperatures, radiant heat on the roof, and included the beneficial effect of passive solar gain through the skylights. Illumination levels inside a building for different skylight areas and types were also calculated.

The design illumination level, available natural light, type of artificial light, and control system define the energy used to provide artificial lighting. The results show the effect of skylight areas on annual lighting system energy usage on an hour-by-hour basis throughout the year and allow the effects of different patterns of building use to be assessed.

Data for the energy used by heating and lighting systems were then converted into equivalent CO_2 emissions to show the overall effect that skylight areas have on total CO_2 emissions.

The findings prove conclusively that skylights provide an overall energy benefit – with the level of that benefit depending on many factors, particularly the area of skylights installed, design illumination level, type of artificial lighting control used, and the pattern of building use.

CO_2 Reduction

Lighting level is measured in lux. The level of lighting required within a building will depend upon the building's use. The model created by the research allows lux levels to vary (accompanying illustrations use 300 and 600 lux). A light level of 300 lux is relatively low (adequate only for general activities that don't require the perception of detail), so it is suitable for circulation spaces and assembly halls. A light level of 600 lux is ideally needed where a degree of color judgement is required or more detailed visual tasks were taking place, such as in many retail, production, and office environments.

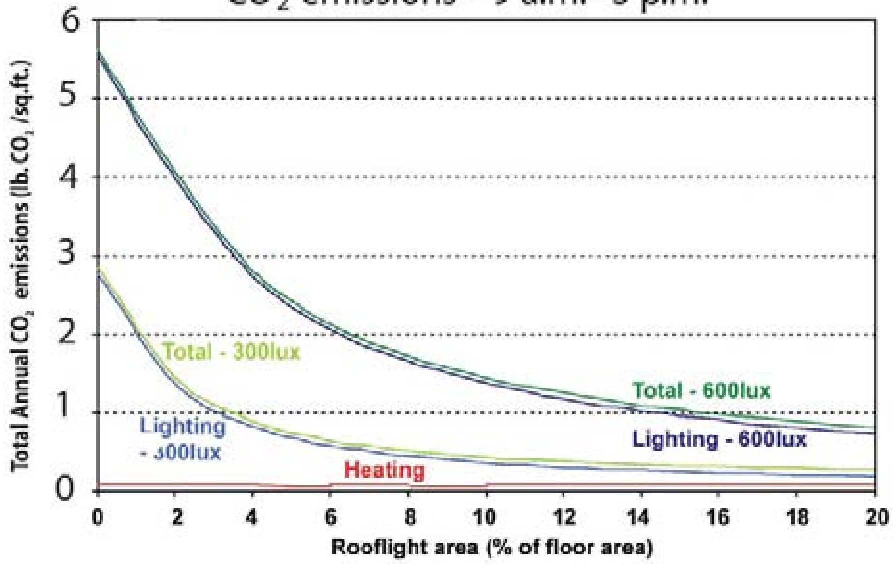
Figure 1 clearly shows that the greater the skylight area, the less artificial light is required and the lower the total power consumption. The higher the illumination level, the greater the lighting system's power consumption will be – and the greater the savings that is offered by an increase in the skylight area.

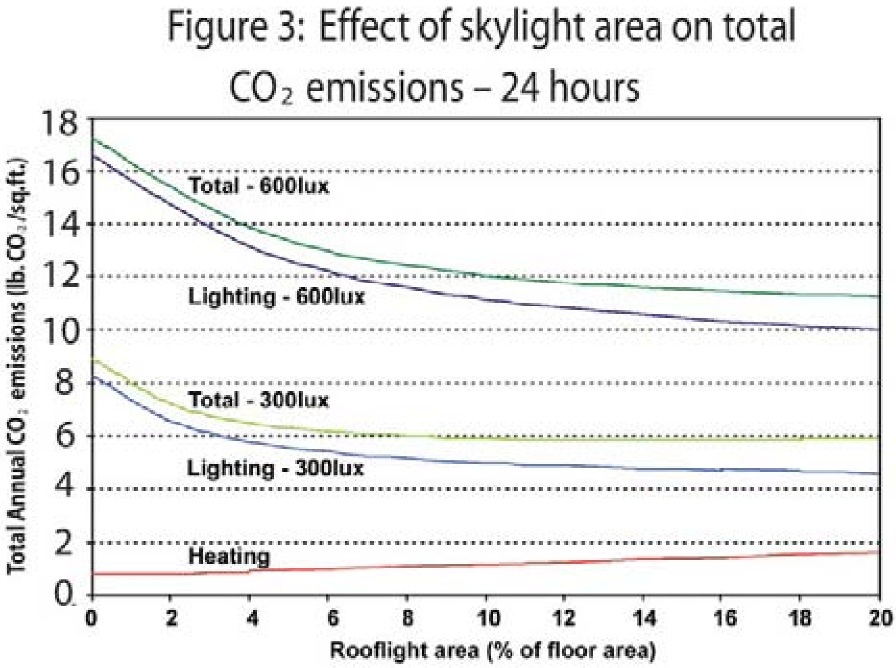
For example, with 300 lux illumination and 9 a.m. to 5 p.m. use, there is a reduction in annual CO_2 emissions due to the lighting system from 14 to 1 kg CO_2/m^2 (2.87 to .205 lbs CO_2/ft^2) as skylight area increases from 0 to 20%. As hours of usage increase, the overall energy use also increases and so do the savings: a savings of 18 kg CO_2/m^2 (3.69 lbs CO_2/ft^2) per annum is made for 24-hour use. At an illumination level of 600 lux, an increase in skylight area from 0 to 20% results in a savings of 24 kg CO_2/m^2 (4.92 lb CO_2/ft^2) for 9 a.m. to 5 p.m. use and 33 kg CO_2/m^2 (6.765 lb CO_2/ft^2) for 24-hour use.

Increasing the skylight area reduces the need for artificial light, cuts the energy requirement of the building, and reduces CO_2 emissions. Increasing the skylight area is a straightforward way of helping to meet target CO_2 emissions levels imposed by England's new Building Regulations. They will take a holistic approach to energy use within buildings with target CO_2 emissions values for the entire structure rather than target U values for each building element.

Figure 2 shows the total effect of skylight area on CO_2 emissions for a building used 9 a.m. to 5 p.m. when the effects of heating and lighting systems are added together. The red line shows the effect on

Figure 2: Effect of skylight area on total CO_2 emissions – 9 a.m. - 5 p.m.





emissions due to the energy use of the heating system, the blue line shows the effects on emissions due to the energy use of the lighting system for both 300 and 600 lux (as shown in *Figure 1*) and the green lines show the sum total of heating and lighting.

The graph shows that an increase in skylight area (at least within the range 0 to 20%) will result in a reduction of total CO_2 emissions. We have already established that when skylight area is increased, the requirement for artificial light decreases. Based on previous assumptions, when heating is considered, the energy requirement was expected to increase. The research proves that for a building occupied primarily during the day, this is not the case. Passive solar gain through the skylights actually cuts the energy requirement further.

A building with 20% skylights occupied 9 a.m. to 5 p.m. for 365 days a year with a lighting requirement of 600 lux will save 24 kg CO_2/m^2 (4.92 lb CO_2/ft^2), or a massive 85% savings in CO_2 emissions from lighting and heat loss through the roof compared to the same building without skylights.

The worst-case scenario for skylights is a building that is occupied 24 hours a day, because during the night there are no benefits either from natural light or passive solar gain. But even in this situation, skylights still provide a very significant energy benefit.

With a lighting requirement of 600 lux (as can be seen in *Figure 3*), the total energy use continues to drop as the skylight area increases. Where the lighting requirement is only 300 lux (which is relatively low), energy consumption continues to fall as the skylight area increases, until it reaches 14%. It then remains approximately constant up to a skylight area of 20%.

Skylights, therefore, offer a considerable energy benefit. However, the research also highlights the importance of appropriate lighting controls to maximize this benefit. Without automated lighting controls, the lights are often left “on” even when they are not needed, losing the considerable savings that skylights offer. Simple “on/off” automated lighting controls that turn all lights “on” when lighting levels fall below the required lux level provide considerable savings. A proportional system that introduces only enough artificial light to maintain the required lux levels provides maximum savings. All graphs have assumed a proportional control system that gives maximum savings, but the trends are the same with a simpler “on/off” lighting control system and

Increasing the skylight area reduces the need for artificial light, cuts the energy requirement of the building, and reduces CO_2 emissions.

the savings remain considerable. The graphs shown have assumed a lighting system that uses $3.75W/m^2/100lux$, the reference figure in the ODPM (Office of the Deputy Prime Minister) consultation document on amendments to Part L (July 2004).

The research proved that in most situations, the greater the area of skylights, the greater the energy savings. It found no situation where increasing skylight area increased energy consumption.

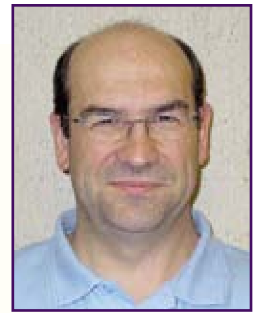
These important findings should have a dramatic impact on how buildings are designed in the future. The forthcoming new Building Regulations [in England] will, for the first time, take into account not only how much energy is leaking out of the structure, but also how much energy is being used to enable the building to function. Skylights impact the building's energy usage in three ways:

- Energy saved by replacing artificial lighting with adequate natural light ***– a positive effect***.
- Heating energy that is saved as a result of passive solar gain ***– a positive effect*** (but a complex one as the design of the building and the other construction materials used will determine how much benefit is derived from passive solar gain).
- Heat loss through the skylight or glazing ***– a negative effect***.

The overall effect of skylights is to save energy. Increasing the area of skylights is one way of reducing a building's annual CO_2 emissions. Providing a bright, naturally-lit interior will create a more pleasant environment, raise peoples' levels of concentration, improve the building's functionality, and reduce its energy consumption – surely a win/win scenario.

Editor's Note: This article, originally titled, "Rooflights Save Energy," is reprinted with permission from the November 2005 issue of RCi (Roofing Cladding & Insulation), *a roofing magazine published by Unity Business Press of Kent, England. The article is based on conditions in the United Kingdom and graphs have been converted from metric to imperial units by the author for reprint in* Interface*. All references to "rooflights" have been changed, for North American consumption, to "skylights."*

Bill Hawker



Bill Hawker is technical director at Brett Martin Daylight Systems in Coventry, England. With a master of science in polymer technology and a qualification in mechanical engineering, Hawker is a leading authority on daylighting with skylights in the U.K. He is chairman of the technical committee of the National Association of Rooflight Manufacturers (NARM) and is heavily involved in the DeMontfort Research.