# Designing with rooflights

## Supporting the guidance in ADL2A & ADL2B (2010)

National Association of Rooflight Manufacturers

# CONTENTS

# SCOPE

- This document gives guidance on the use of natural daylight via rooflights to provide compliance with Building Regulations L2 – Conservation of Fuel and Power for Buildings other than Dwellings as amended in 2010

- This document only applies to England and Wales. Technical Document F in Northern Ireland has a similar basis, whilst Scotland have their own Regulations under section 6; overall principles will be the same but the detail may vary.

- This document covers both Approved Document L2A (ADL2A) which applies to New Work and Approved Document L2B (ADL2B) which applies to Repairs, Refurbishment and Extensions and should be read in conjunction with the authorised documents issued by the Department for Communities & Local Government (CLG).

- Note that large extensions to existing buildings, where the total floor area of the extension is greater than 100m$^2$ and greater than 25% of the total floor area of the existing building, are treated in the same way as new build and fall under the control of AD L2A

- This Guidance does not cover Dwellings, or Approved Document L1

- Note that Dwellings relate to self contained units only. However, buildings exclusively containing Rooms for Residential Purposes such as nursing homes, and student accommodation or similar, are not considered as dwellings and therefore such buildings come under the control of ADL2

- Buildings that fall outside the requirements of Part L, e.g. unheated agricultural buildings, are not covered by this document. Industrial sites, workshops and agricultural buildings with low energy demand for heating or cooling are exempt from the Part L Regulations. Note that warehouses (for example) with a low energy demand are not exempt since they are not buildings in the exempt category.

- Note that such buildings, with low energy demand that are not exempt, may be built with less demanding requirements. However, be aware that a subsequent change of use for the building may require the building to be upgraded to fully meet ADL2A requirements and such a fit out could be far more expensive than complying with ADL2A at the new build stage – (refer to AD L2A para 3.8 to 3.11)

- This document does not give guidance on the use of vertical windows

- It does not give guidance on matters that have no bearing on the use, effect and control on natural daylighting into buildings

- Reference will be made to the Simplified Building Energy Model (SBEM) software (which is a free-of-charge approved calculation tool referenced by ADL2A Section 4.3a to determine building compliance) including guidance on how various rooflight systems should be entered into SBEM. This document does not cover other approved software tools.

- Reference will also be made to the National Calculation Methodology modelling guide (NCM) which provides the data that is embedded within SBEM.

- This document provides background information on the research carried out by De Montfort University (DMU) into the impact of rooflights on the overall energy demand and the associated carbon dioxide ($CO_2$) emissions. It shows that as rooflight area is increased up to 20% of the floor area, $CO_2$ emissions will generally decrease as the contribution of natural daylight through rooflights replaces the need for artificial lighting.

- Via examples using SBEM, this document will demonstrate the need to consider the total lighting demand for a building and to use light saving devices for all installed artificial lighting.

- It does not make any recommendation on the types of artificial lighting or lighting control that may be used to supplement the natural daylight provided by rooflighting.

## DEFINITIONS WITHIN AD L2

The following terms are used within the 2010 Part L Regulations and are referred to in this document.

- **Thermal Element**
  This is defined as the fabric of the building to include floor, walls and roof but does not include windows, rooflights and doors.

- **Controlled Fittings**
  Rooflights, along with windows and doors, are not considered as part of the “fabric” of the building but are regarded as Controlled Fittings and considered separately from the building fabric.

- **Fixed Building Services**
  This includes fixed internal artificial lighting systems and fixed systems for heating, air conditioning and mechanical ventilation.

- **Notification**
  All new buildings must be notified to the Building Control Body (BCB) prior to the work starting, complete with a full set of SBEM data to show compliance, and then again when the building is completed to show that full compliance has been achieved. Note that Self Certification schemes by Competent Persons are available.

## INTRODUCTION

The Building Regulations Part L 2010, designed to save energy and power consumption in buildings, is the latest phase of an on going legislative programme by Government with further updates planned over the next 9 years to create a long term building stock that will generate an ever decreasing release of $CO_2$ into the atmosphere. The new Regulations came into effect on 1st October 2010.

In 2002 Part L concentrated on elemental standards for the fabric of the building and its services. In 2006 Part L looked for the first time at the overall energy use of the building and associated $CO_2$ emissions, and aimed to improve the energy efficiency of operating the building by approximately 25%, compared to a Notional Building (based on the 2002 design). The energy compliance was carried out using approved software such as the Simplified Building Energy Model (SBEM). The 2006 Regulations considered not only the fabric of the building, but very importantly, the energy efficiency of the heating, artificial lighting, cooling and domestic hot water.

The 2010 Part L Regulations take this process forward and require a significant further improvement in energy efficiency. Buildings now have to perform at least as well as a new Notional Building, based on new 2010 standards for both fabric and services; the level of improvement in energy efficiency compared to 2006 will vary from building type to building type. This will be achieved by further improvements in the building fabric, reducing air leakage, attention to excessive solar gain which leads to the need for air conditioning, radical review of automatic controls for artificial lighting systems and improved efficiency of boilers for space heating and hot water supply. The 2010 Regulations provide minimum standards of performance (fall back levels), however it is clear from the data embedded into SBEM software, that buildings designed solely to the minimum standards, will not be compliant. Designers and builders will need to look at every element of the design and services of their building and seek to achieve performance improvements over the fall back requirements.

# DESIGNING WITH ROOFLIGHTS TO SAVE ENERGY

Independent research carried out in 2005 by De Montfort University proved conclusively that rooflights 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 rooflights 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 people want to spend time in and contribute to the government's target to reduce emissions of $CO_2$.

The primary reason for including rooflights 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 is a completely free, unlimited natural resource. Whilst artificial light is essential, it's provision uses a lot of energy, so reducing the requirement will dramatically cut energy use, and the $CO_2$ emissions which result from this.

There has previously been a widely held view that whilst rooflights 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. Recent research has confirmed this view is wrong.

Increased rooflight area can dramatically reduce the energy requirements of lighting systems whilst resulting in a much smaller increase in energy requirements of the heating system, but the relative effects depend on a number of other parameters for the building, such as temperature set point, hours of occupancy, and internal gains, as well as the details of the building construction. The savings in total energy costs and carbon footprint therefore vary from building to building, but are usually found to be positive as rooflight area increases often up to 20% of the roof area for large buildings with internal work height greater than 6m and up to 15% rooflight area for buildings of lower than 6m work height.

The Institute of Energy & Sustainable Development at Leicester's De Montfort University (DMU) have investigated the effect that rooflights have on the total energy needed to operate a building, and the annual $CO_2$ emissions which result from this. This research used the highly sophisticated EnergyPlus software, and analysed annual data on an hour by hour basis for very accurate prediction. Contrary to traditional belief, the research proved that installing an appropriate level of rooflighting (typically 15% - 20% of the roof area) will usually reduce overall energy consumption, and the associated $CO_2$ emissions, in addition to providing the widely recognised benefits of natural daylight within a building environment. Their work is summarised in Appendix 2 of this publication.

The Simplified Building Energy Method (SBEM), the free-of-charge computer modelling package used to demonstrate compliance with Part L2A Building Regulations, uses the same principles as the DMU research, and so also recognises the contribution to energy saving and reduction in $CO_2$ emissions which are offered by the inclusion of high levels of rooflights.

Many factors affect the contribution which rooflights can make, and hence the optimum area of rooflights will vary from building to building. However, in general, the conclusions of the DMU work (reflected in results from SBEM) show that rooflights always make a positive contribution: omission of rooflights or reduction of rooflight area gives a very significant increase in $CO_2$ emissions, and that savings offered by rooflights are dramatic:

- Typically the total $CO_2$ emissions associated with all aspects of operating a building without rooflights can be over 50% higher than for a building with 12% rooflights
- in almost all relevant buildings, savings continue to be achieved as rooflight area is increased up to and beyond 15% of floor area
- in some buildings (typically with higher illumination requirements, and used predominantly during the daytime) there are significant further savings as rooflight area increases up to 20% at higher illumination levels
- in other buildings (typically with lower illumination requirements, and used 24 hours a day) the savings as rooflight area is increased from 12% to 15% are relatively minor, with very slight increases in $CO_2$ emissions as area increases further, to 20%

Rooflight area of 15% or more of floor area may therefore be a useful approximation of the optimum rooflight area.

Care should be taken to avoid risk of solar overheating (see guidance on ADL2A Criterion 3, page 11): typically, rooflight area should be limited to 18-20% of floor area in buildings over 6 metres tall, and 12-13% of floor area in buildings less than 6 metres tall.

## ARTIFICIAL LIGHTING CONTROLS

Designers need to recognise that artificial lighting will be essential during parts of the working day and particularly in the winter months, and specifically in working areas where light levels need to remain constant. In order to minimise the use of artificial lighting, thereby maximising the energy savings from natural daylight, artificial lighting should be, where ever possible controlled by automatic means that operate on "need" requirements.

Designers need to bear in mind these key points :-

- The electric light is carbon inefficient in that power from the National Grid is largely generated from burning fossil fuel at modest generation efficiencies.

- Where natural daylight levels are low, without lighting control, the lights in the work place get turned on in the morning and stay on all day, regardless of the need for them.

- Natural daylight through rooflights is completely free, provides some useful solar gain and makes the work place a more pleasant environment.

The DMU work highlights the importance of appropriate lighting controls to maximise the benefits of natural light via rooflights. The use of on/off photo electric cells and proportional lighting controls will save considerably on energy use. This document does not detail all the options that are available, however a Joint Document from NARM and the Lighting Industry Federation (LIF) called **"Designing with Rooflights and Controlled Artificial Lighting to reduce $CO_2$ emissions – supporting the requirements of the Building Regs Part L2A & L2B"** is available on the NARM web site www.narm.org.uk

## AD L2A NEW BUILDINGS OTHER THAN DWELLINGS

**General Comment**
The latest Part L Regulations came into force on 1st October 2010. The ADL2 document is an Advisory Document. It provides the detail of criteria to be achieved, it provides "fall back" minimum standards that **must** be achieved but does not advise how compliance can be achieved. The detail is "hidden" within the compliance software – the Simplified Building Energy Model (SBEM) or other approved software programs. Further information on the embodied data can be obtained from the "National Calculation Methodology (NCM) modelling guide (for buildings other than dwellings in England & Wales) 2010 edition".

The concept is that designers and builders are free to design and build provided they achieve the minimum standards in all areas and that the SBEM calculation produces a compliant result. It should be noted that unless high standards of specification and build are maintained through out, compliance will be difficult to achieve. As a word of caution, if builders and subcontractors do not fulfil the complete design specification, or use alternative (cheaper) materials than specified, it is likely that compliance will not be achieved on completion.

## 5 CRITERIA

AD L2A defines 5 Criteria to achieve Compliance:

Criterion 1 : The BER shall not exceed the TER (ie a limit on $CO_2$ emissions arising from operation of the building)

Criterion 2 : Design flexibility is limited to the minimum "Fall Back" standards

Criterion 3 : The effect of Solar Gain in the summer should be limited.

Criterion 4 : The Building Performance is consistent with the stated BER.

Criterion 5 : Provision for Energy Efficiency Operations of the Building. (This section is not Covered in this document )

Note that Criterion 1 is a regulation and is therefore mandatory, whereas Criteria 2 to 5 are only for guidance.

# **CRITERION 1** THE BER SHALL NOT EXCEED THE TER

**Target ($CO_2$) Emission Rate (TER)**
The TER is the maximum $CO_2$ emission rate that is allowable for any new build. It is expressed in terms of the mass of $CO_2$ emitted per year per sq. metre of the total useful floor area of the building ($kg/m^2/year$).

The TER is calculated for a Notional Building of the same area and shape of the actual building that is being proposed, based on the data within the NCM modelling guide. The version of SBEM used to show compliance with AD L2A 2010 (SBEM v4 onwards) uses a new Notional Building, reflecting current best practices, and unrelated to previous definition of the Notional Building.

**Building Emission Rate (BER)**
The BER is the $CO_2$ emission rate for the actual building, calculated in exactly the same way as the TER but based on the properties of the actual rather than Notional Building.

All the data for the actual building (geometry and full details of the building fabric and building services) are entered into SBEM which calculates and compares the BER and the TER. If the BER< or = TER then the building is compliant.

It is mandatory that the BER is less than or equal to the TER. How this is best achieved for rooflights is explained in this document and demonstrated in Appendix 1.

**Notional Building Specification**
SBEM uses one of 3 different Notional Building specifications, determined by the activity within each area of a building:

- Rooflit (eg warehouses, sports halls, industrial premises)
- Sidelit (eg offices, classrooms)
- Unlit (eg theatres, storage cupboards)

The specification for each is defined with the NCM modelling guide; for all rooflit areas the specification includes:

- 12% rooflight area
- Rooflight U-value 1.8 $W/m^2K$
- Rooflights with 67% light transmission and 15% frame factor
- Proportional control of artificial lighting systems, with continuous parasitic power that is the lesser of either 3% of the installed lighting load or 0.3$W/m^2$

Note that the illumination provided by rooflights is defined by the product of:

Area (12%) x light transmission (67%) x frame factor (1-15%=85%)

and will consequently be unchanged provided the product remains the same, even if each individual parameter is different: for example, if light transmission is 54% and frame factor is 12% then the same illumination is provided by a rooflight area of 14.4%, because:

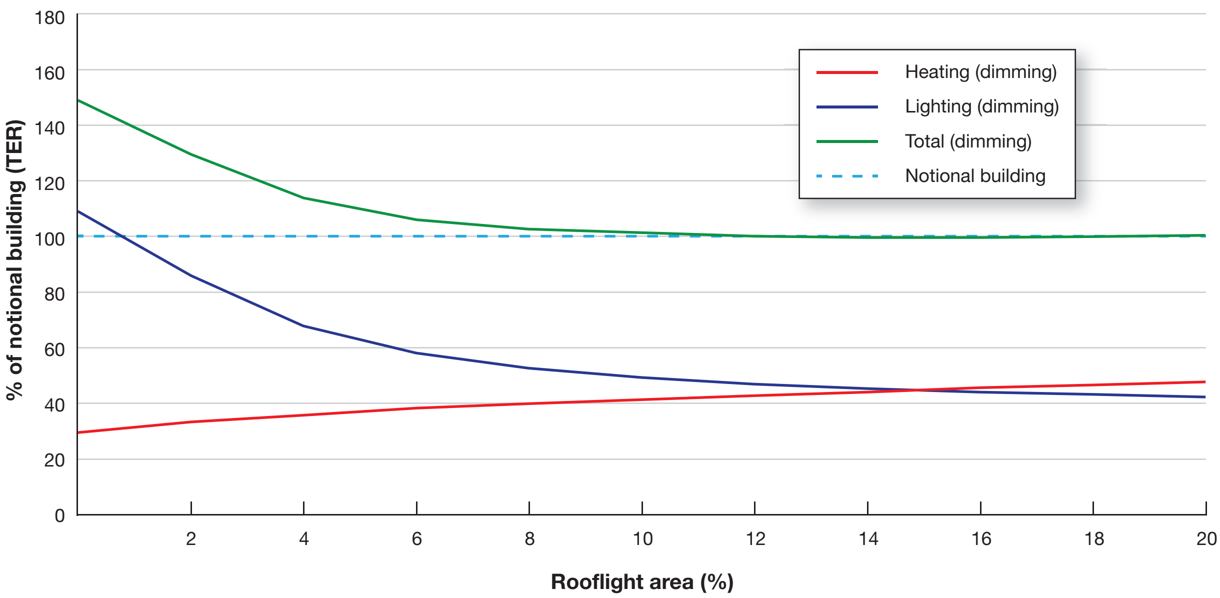
14.4% x 54% x 88% = 12% x 67% x 85%
(= 0.06834)

## SBEM Results

If an actual building is modelled within SBEM with all parameters defined exactly in accordance with the Notional Building (including 12% rooflights with 67% light transmission and proportional control of the electric lighting system), then the SBEM results show the same $CO_2$ emissions for the actual and notional buildings (ie emissions of actual building = 100% of notional building)

If all other parameters are then left unchanged, but rooflight area is altered, the following graph shows the effect on total $CO_2$ emissions:

**Graph 1:** SBEM results - $CO_2$ emissions for the Notional Building at varying rooflight area

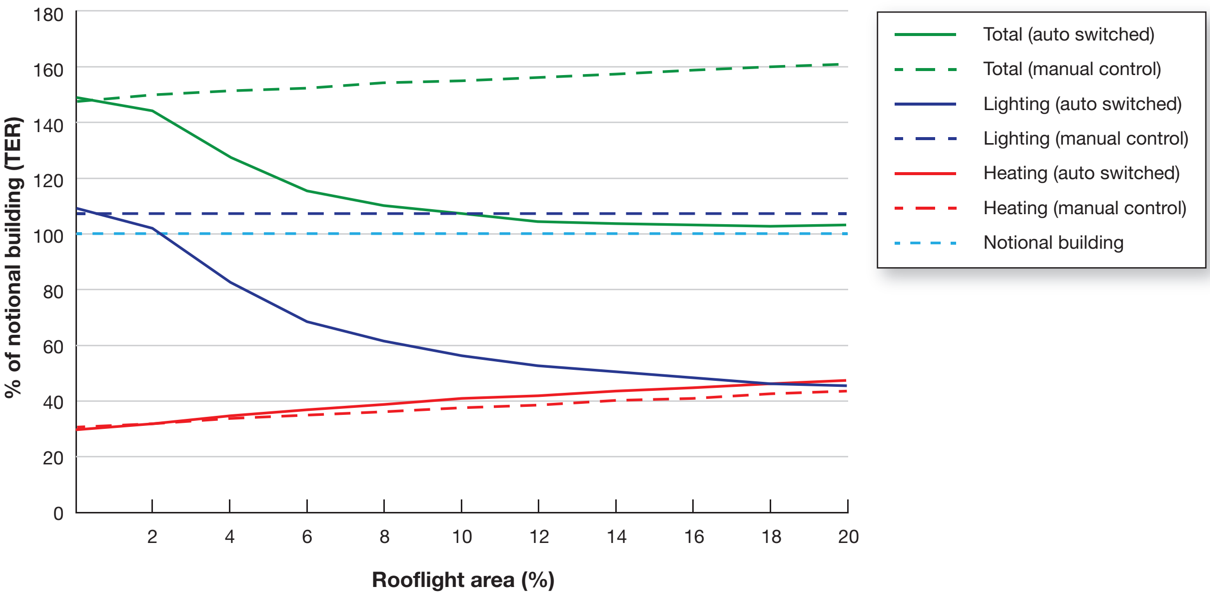



It can be seen from this graph that:

- at 12% rooflight area the actual building has exactly the same overall $CO_2$ emissions as the notional building (100%)
- as rooflight area is reduced there are dramatic increases in $CO_2$ emissions due to use of the lighting system, and in total $CO_2$ emissions, whilst there are smaller reductions in the $CO_2$ emissions due to use of the heating system
- if rooflights are omitted entirely, total $CO_2$ emissions from all aspects of operation of the building are 50% higher than they are with 12% rooflights
- if rooflights are omitted entirely, $CO_2$ emissions from the lighting system are 230% higher than they are with 12% rooflights
- if rooflights are omitted entirely, $CO_2$ emissions from the lighting system alone are higher than the total permissible $CO_2$ emissions from all aspects of operation. This does not mean that rooflights cannot be omitted, but it does mean that the efficiency of the lighting system would have to be dramatically improved compared to the specification in the notional building, which already reflects current good practice
- as rooflight area is increased from 12% to 20% there is a small reduction in $CO_2$ emissions due to use of the lighting system, almost balanced by a small increase in $CO_2$ emissions due to use of the heating system, so there is little change in total $CO_2$ emissions

The following graph shows the same data, when less sophisticated lighting control systems are used – both a simple auto switched on-off system rather than the proportional (dimming) systems which is defined in the notional building, and when there is no automatic control of the lighting system.

**Graph 2:** SBEM results – effects of lighting control system at varying rooflight area



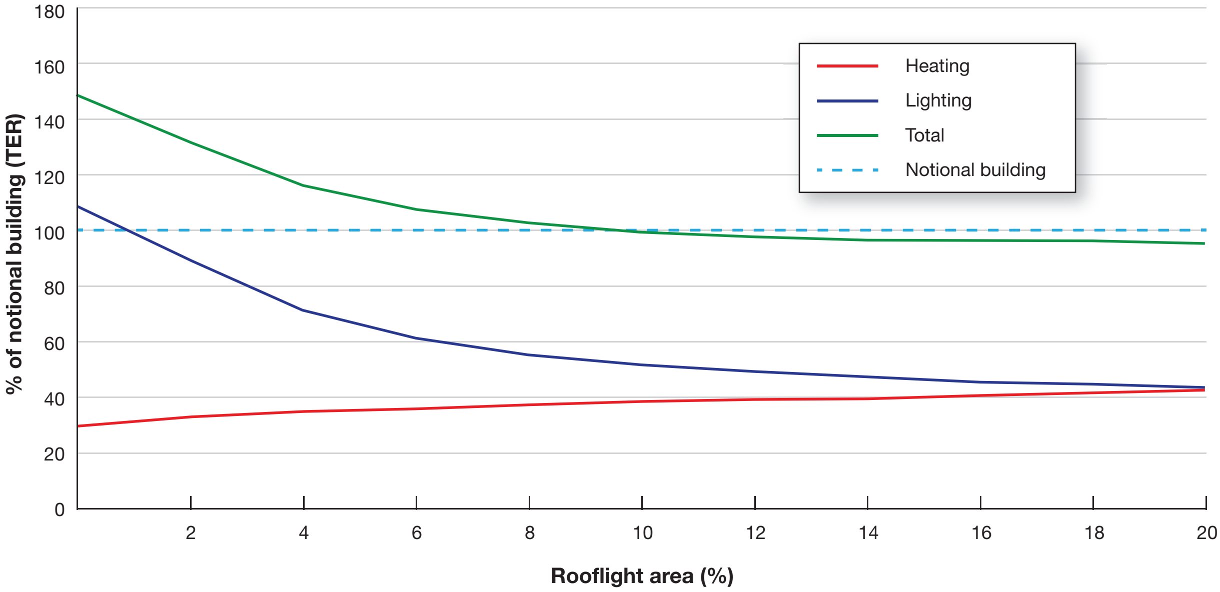

This graph shows that:

- with a simpler auto switched (on-off) system, total $CO_2$ emissions are slightly increased, and the building does not achieve compliance. Other improvements to the building will be required to compensate for the increased energy use of the lighting system
- without automatic control of the lighting system SBEM assumes the lights stay on all the time (which is probably an accurate reflection of many applications), so the $CO_2$ emissions due to use of the lighting system are constant, at the same level as if there were no rooflights
- without automatic control, $CO_2$ emissions from the lighting system alone are higher than the total permissible $CO_2$ emissions from all aspects of operation, regardless of rooflight area. This does not mean that lighting systems must be automatically controlled, but it does mean that if they are not, the efficiency of the lighting system would have to be dramatically improved compared to the specification in the notional building, which already reflects current good practice

The above graphs assume that all properties of the actual rooflights are identical to those specified in the Notional Building: U-value 1.8 W/m²K, light transmission 67% and frame factor 15%. In practice, rooflight properties may be different – for example they may have slightly lower light transmission, and slightly better insulation. As an example, the following graph shows the performance of an actual building specified exactly in accordance with the Notional Building, but with:

- Light transmission 54%
- U-value 1.3W/m²K
- Frame factor 12%

**Graph 3:** SBEM results – effect of varying rooflight area on $CO_2$ emissions for an actual building with realistic rooflight properties and dimming light controls




It can be seen from this graph that the overall trends are the same as with the notional specification rooflights: as rooflight area is reduced there are dramatic increases in $CO_2$ emissions due to use of the lighting system, and in total $CO_2$ emissions, whilst there are smaller reductions in the $CO_2$ emissions due to use of the heating system.

The graph also shows that in this case, the actual rooflights perform slightly better than the notional rooflights, so that:

- the total $CO_2$ emissions of the actual building with 12% rooflights are slightly better than the notional building (offering 2-3% reduction in total $CO_2$ emissions)
- if rooflights are omitted entirely, $CO_2$ emissions from the lighting system are 230% higher than they are with 12% rooflights
- if rooflights are omitted entirely, total $CO_2$ emissions from all aspects of operation of the building are 50% higher than they are with 12% rooflights (the same as shown in the first graph, with notional specification rooflights, since rooflight specification makes no difference when they are omitted)
- as rooflight area is increased from 12% to 20% the reduction in $CO_2$ emissions due to use of the lighting system is greater than the increase in $CO_2$ emissions due to use of the heating system, and total $CO_2$ emissions are reduced to 5% less than the notional building

## **CRITERION 2** LIMITING DESIGN FLEXIBILITY

In addition to limits on overall $CO_2$ emissions, Criterion 2 also sets limits on the worst acceptable standards for both elements of the building fabric, and services. Limits on the insulation values for the Building fabric are given in ADL2A Table 4:

| **AD L2A Table 4 Limiting fabric parameters** | |
|---|---|
| Roof | 0.25 W/m$^2$.K |
| Wall | 0.35 W/m$^2$.K |
| Floor | 0.25 W/m$^2$.K |
| Windows, roof windows, rooflights, curtain walling and pedestrian doors | 2.2 W/m$^2$.K |

Note that the limit of 2.2W/m$^2$K for rooflights is:

- the limiting U-value for windows and rooflights assumes the glazing has been assessed in the vertical position, even though rooflights are usually used horizontally. If a rooflight is assessed horizontally the limit should be increased by 0.3 W/m$^2$K (see AD L2A para 4.32 and BR443 section 11.1) so the limiting value is 2.5 W/m$^2$K when manufacturers quote rooflight performance horizontally, as they are used.

- based on the developed area of the rooflight, not the area of the roof aperture, which is defined in NARM Guidance Note NTD2

The above table defines the worst acceptable performance for each element of the building; it should be noted that the Notional Building as detailed under Criterion 1 above are significantly higher performance, and if an actual building only complies with the worst acceptable values for building fabric and services, then it will be considerably poorer performance than the Notional Building and will fail Criterion 1.

Specifiers may therefore opt to specify rooflights with an improved U-value to match or exceed the U-values used in the Notional Building as one way of meeting Criterion 1.

Note that “plastic” rooflights will need to be at least triple skin in order to achieve the worst case U-value of 2.2W/m$^2$K.

To achieve higher levels of performance, rooflight manufacturers will modify the internal air gap and the internal design of the middle skin. Since this is design variable but could be critical to achieving the TER, builders and contractors need to be fully aware that changing the specification or the nominated supplier to buy cheaper options, may well fail building compliance, thus incurring far greater additional cost to reinstate the correct specification.

For buildings that produce high internal heat gains due to the process within the building, a less demanding weighted average U-value for rooflights may be an appropriate way to reduce overall $CO_2$ emissions and hence the BER. In such a case, the rooflight U-value may be higher than 2.2 but it should never be higher than 2.7 W/m$^2$K, which will still necessitate triple skin rooflights.

## **CRITERION 3** LIMITING THE EFFECT OF SOLAR GAIN IN SUMMER

The Regulations define measures to avoid overheating in the summer period – one of which is to limit glazed areas (windows and rooflights) to limit the solar load to limit the requirement for air conditioning.

It should be borne in mind that solar gain through windows and rooflights is just one aspect of internal gains within the building. People (including their density and activity), artificial lighting, display lighting, process equipment, computers and other equipment all contribute to internal heat gains, and along with ventilation strategy have an effect on the potential for excess heat build up.

The Regulations place limits on both window and rooflight area to limit the solar loads; they recognise the effect of solar gain is influenced by the height of the building due to the effects of stratification and the height of the rooflights above the work zone and the limits on rooflight area in AD L2A Criterion 3 para 4.44, vary depending on the building height, as follows:

| Zone Height | Max Rooflight Area | Frame Factor | g value* |
|---|---|---|---|
| < 6m | 10% | 25% | 0.68 |
| > 6m | 20% | 15% | 0.46 |

* The g value is a measure of the total transmitted solar energy: it is the direct transmission in the total solar spectrum plus the proportion of absorbed energy which is retransmitted internally.

Note that the solar load through the rooflights is defined by the product of:

Area x g-value x frame factor

and the glazing area limit will consequently be met provided this product remains the same, even if each individual parameter is different.

For example, for a taller building, if the g-value is 0.51 rather than 0.46, then the limit on rooflight area in will be reduced from 20% to 18%, because:

18% x 0.51 x 85% = 20% x 0.46 x 85%
(= 0.0782)

and similarly for a lower building, if the g-value is 0.51 rather than 0.68, then the limit on rooflight area in will be increased from 10% to 13.3%, because:

13.3% x 0.51 x 75% = 10% x 0.68 x 75%
(= 0.051)

SBEM considers the glazed areas (including both windows and rooflights) for each individual zone of the building on the above basis, taking into account the glazed area and frame factor in the zone, the height of the zone, and the glazing g-value, and output shows whether the glazed area limits have been met (and how close to the limits each zone is).

In general, these limits are not usually exceeded for rooflight areas up to 17-20% in buildings over 6m tall, or for rooflight areas up to 10-15% in lower buildings, although care should be taken if there are also large areas of window in the same zone, as this could cause total glazed area to be exceeded.

Solar gain should only be considered for work zones where a person will be working for a substantial part of the day. It should not be considered for circulation spaces, transient occupancy such as toilets and spaces not intended to be occupied.

## **CRITERION 4** BUILDING PERFORMANCE CONSISTENT WITH BER

The Regulations require that most buildings that are not dwellings must be tested for air tightness on completion of the building structure, and the worst case acceptable value (under Crierion 2) is $10m^3/hr/m^2$ at 50 Pa.

In addition to meeting the worst case value, the measured air permeability must be entered into SBEM and the BER recalculated accordingly, and must still meet the TER – which is based on the Notional Building which uses a value of $5m^3/hr/m^2$ at 50 Pa. This may create a problem if the BER at design stage was calculated with an assumed air permeability which is not met in practice.

Buildings of less than $500m^2$ may not be subject to the air pressure test, but if not, the BER calculation will use the result of $15m^3/hr/m^2$ at 50Pa. This will result in compensation improvements in other elements of the fabric and services to maintain the BER is no worse than the TER.

This performance is very demanding, particularly on smaller buildings up to 1500 $m^2$ and attention to fine detail in the construction of the building will be critical.

For rooflights, attention to the detail of the fixing process is critical. In particular, the correct type, size and positioning of sealant, and correct compression of sealant by the use of the correct number, position, size and type of fasteners is vital. It must be noted that “in plane” rooflights to match the opaque sheeting of the roof have a different performance and fixing specification than the opaque sheeting and this must be observed by the fixer to ensure both water and air tightness. The consequences of failing the air pressure test will mean that remedial work will need to be carried out and likely to prove very expensive for those concerned.

## SUMMARY OF THE REQUIREMENTS OF AD L2A ON ROOFLIGHTS

- Criterion 1 of Approved Document L2A of the 2010 Regulations is looking for large overall savings in energy use and associated $CO_2$ emissions, so that an actual building matches the performance of a new Notional Building.

- The major savings will need to come from the building services. Some improvement will come from improving the U-value of the building fabric but the impact of more and more insulation is a law of diminishing returns.

- Rooflights offer opportunity for dramatic savings in the overall $CO_2$ emissions by reducing the use of electric lighting systems, often the biggest source of $CO_2$ emissions when operating a building.

- Rooflights are also a very positive means of saving energy. Natural daylight is free and provides the essential feel good factor at the place of work and as a result people work more efficiently. Rooflights are an ideal way to reduce the building energy demand when designers are struggling to find that additional energy saving that will achieve compliance.

- The Notional Building has 12% rooflights. Rooflight area in the actual building is critical to matching the TER and achieving compliance: omission of rooflights can increase the total $CO_2$ emissions by 50% making compliance very difficult.

- Specification of as high a rooflight area as practical, with rooflights as well insulated as possible, should be considered to help meet the TER and achieve compliance.

- Automatic control of artificial lights is critical to harness the benefits offered by rooflights and achieve compliance; manual light switching in a work zone is unlikely to provide a compliant building. Proportional (dimming) control is better than switching (on/off) automatic control.

- Criterion 2 requires that rooflights should have a U-value of 2.2W/m$^2$K, which means they should be at least triple skin. Use of rooflights with a U-value of 1.8 W/m$^2$K (to match the Notional Building) or significantly better U-values can be considered by the specifier as a useful way to help meet the TER, but this is not a requirement.

- Criterion 3 sets limits on glazed areas to avoid excessive solar load and care should be taken not to exceed these areas – typically 17-20% for buildings over 6metres tall, and 10-15% for lower buildings.

- Attention to detail on the fixing of rooflights to the manufacturers recommendations will be critical to achieve a compliant Air Permeability test and achieve Criterion 4.

- Designers/builders will require full technical details from the NARM manufacturer which will include - U-value, frame factor, light transmission and g value. These will vary dependant on the product, design and manufacturer. The data input into SBEM may be very critical to achieving Compliance. Contractors need to be aware that changing the designers specification to save money on product price may lead to a Non Compliant building and resulting extra costs to rectify the non compliance.

- In summary:

    - for work zones < 6m high, rooflight areas should be 10-15% of the floor area.

    - for work zones > 6m high, rooflight areas should be 12-20% of the floor area.

**For a smaller carbon footprint just add rooflights**

# AD L2B WORK ON EXISTING BUILDINGS THAT ARE NOT DWELLINGS

This NARM guidance document is designed to assist the reader to understand the Guidance in AD L2B in respect of the use and application of rooflights.

There are four areas of work to consider :-

- Repairs
- Refurbishments
- New Extensions
- Consequential Improvements

**Buildings exempt from AD L2B**

- Section 1 Listed Buildings and some buildings in Conservation Areas
- Buildings primarily used for worship
- Stand alone buildings of less than 50 $m^2$ useful floor area
- Certain porches and conservatories of less than $30m^2$ where the heating system is not extended into the porch or conservatory
- Certain historic buildings where there is a requirement to match the original building
- Buildings with a low energy demand

**Large Buildings**
Where the extension is greater than $100m^2$ and greater than 25% of the useful floor area of the existing building, then the work is regarded as a New Building and must comply to the requirements of AD L2A. In addition, the requirement for consequential improvements to the original building will also apply, as explained below.

# 1. REPAIRS TO ROOFLIGHTS

Windows, rooflights and doors are defined as Controlled Fittings; this definition includes any frames. If the glazing of a rooflight is being replaced without replacing the frame, then a new Controlled Fitting is not being fitted and AD L2B does not apply (see AD L2B para 4.23).

Consequently, if replacing the glazing of an individual rooflight without replacing the frame (e.g. the upstand or the surrounding opaque sheeting), replacing like with like will be acceptable even if the original rooflight is single skin – although where practical, it would be sensible to upgrade to Part L standards.

Where the glazing of all rooflights on a building is being replaced, even if the frames are not, it is likely to be regarded as refurbishment rather than repair and the requirements of AD L2B will apply; see below.

Where a whole rooflight including the frame ie a Controlled Fitting, is being replaced, then the requirements of AD L2B as detailed below apply.

## 2. REFURBISHMENT TO ROOFLIGHTS

Where rooflights and their upstands or surrounding opaque sheets (thermal elements) are being replaced, then the work comes under the Control of AD L2B and must comply with the Standards specified in AD L2B Table 3

**AD L2B Table 3 Standards for Controlled Fittings**

| **Fitting** | **Standard** |
|---|---|
| Windows, roof windows and glazed rooflights | 1.8W/m$^2$.K for the whole unit |
| Alternative option for windows in buildings that are essentially domestic in character | A window energy rating of Band C |
| Plastic rooflight | 1.8W/m$^2$.K |

**Notes to Table 3**

- These limits on U-values assume the window or rooflight has been assessed in the vertical position, even though rooflights are usually used horizontally. If a rooflight is assessed horizontally these limits should be increased by 0.3W/m$^2$K (see AD L2B para 4.26), so 2.1W/m$^2$K is the limiting value when manufacturers quote rooflight performance horizontally, as they are used.
- For plastic rooflights this will always require a triple skin rooflight
- The relevant rooflight U-value for checking against these limits is based on the developed area of the rooflight, not the area of the roof aperture. See NARM Guidance Note NTD2 for further detail
- Plastic rooflights are normally supplied, in the UK, in Glass Reinforced Polyester (GRP) or Polycarbonate. Other materials are available from abroad but such materials will generally fail the UK requirements for non fragility and/or the fire resistance Regulations.

In buildings with high internal heat gains from a manufacturing process, a less demanding U-value for rooflights may be appropriate. In such cases the requirements to AD L2B Table 3 may be relaxed but the value should not be worse than 2.7 W/m$^2$K, which will still require a triple skin rooflight.

# 3. NEW EXTENSIONS

Work on extensions which are less than 100m$^2$, or are less than 25% of the existing floor area, fall under AD L2B and as a general rule will be measured by the Elemental Method i.e products achieving a minimum specified performance.

However, the use of SBEM to calculate the buildings performance and compare $CO_2$ emissions from the actual building to a Notional Building (as Criterion 1 under AD L2A) can be used as an alternative means to show Compliance (see AD L2B paras 4.9-4.11)

When designing an Extension, Controlled Fittings (including rooflights) should meet the standards shown in Table 3 (see above) - U-values should be 1.8 W/m$^2$K (when measured in the vertical plane, or 2.1W/m$^2$K when measured in the horizontal plane)

The areas of windows and rooflights should not exceed the values shown in Table 2

**AD L2B Table 2 Opening Areas in the Extension**

| Building type | Windows and personnel doors as % of exposed wall | Rooflights as % of area of roof |
|---|---|---|
| Residential buildings where people temporarily or permanently reside | 30 | 20 |
| Places of assembly, offices and shops | 40 | 20 |
| Industrial and storage buildings | 15 | 20 |
| Vehicle access doors and display windows and similar glazing | As required | N/A |

**Comments to Table 2**
If the original building had a rooflight area greater than 20% of the roof area, rooflight area in the extension can match the area in the original building, rather than the areas in Table 2 (see AD L2B para 4.4)

It is also permitted to vary the U-values shown in Table 3 and the opening areas shown in Table 2 provided that the area weighted U-value of all the elements of the extension is no greater than that of an extension of the same size and shape that complies with Tables 2 and 3 (see AD L2B para 4.7-4.8)

The norm for a new extension will be to fit rooflights up to 20% of the roof area with a U-value of 1.8 W/m$^2$K (measured in the vertical plane).

Note that since it will be unlikely that a SBEM calculation will be carried out which will verify the point, designers need to recognise that, where appropriate, it is essential to incorporate rooflights into the design to reduce the carbon footprint of the building.

**Conservatory Extensions**
Where the extension is a Conservatory or a Porch and is not exempt, then reasonable provision will be :-

- Effective thermal separation between the existing building and the extension
- Independent temperature and on/off controls within the extension
- Glazed area should meet the Standards to Table 3 above. However the limitation to total glazed area in Table 2 will not apply

# 4. CONSEQUENTIAL IMPROVEMENTS

Where an existing building has a floor area over 1000m$^2$, and work is to be carried out on the building by way of an extension, or the initial provision or a capacity increase of any fixed building services, then a requirement **for consequential improvement** to the building is triggered.

These are to improve the energy performance of the original building, in addition to the proposed building work (the "principal works"), and should be to a value of at least 10% of the principal works. The principal works must still comply with Part L in the normal way.

Consequential improvement is only required if both technically and economically feasible, the latter defined by a simple payback of 15 years (see AD L2B Key Terms 3.1)

AD L2B provides a list of 9 possible measures to upgrade the original building in Table 6 "Improvements that in ordinary circumstances are practical and economically feasible"

Item 7 in AD L2B Table 6 identifies "Replacing existing windows, roof windows or rooflights or doors which have a U-value worse than 3.3 W/m$^2$K" as one such measure, and this example is used in the text (see AD L2B para 6.4).

If, as well as extending a building, old rooflights that have U-values greater than 3.3 are replaced with new rooflights that have U-value of 1.8 W/m$^2$K (when measured in the vertical plane) this would satisfy the requirement for consequential improvements, provided the cost of the rooflight replacement was at least 10% of the cost of the extension.

Since there will be a basic requirement for this level of financial commitment to upgrade the original building there will be considerable advantage to selecting this option as the method of providing consequential improvement, since:

- There will be considerable thermal efficiency savings by replacing old rooflights at a U-value in excess of 3.3 W/m$^2$K with new rooflights at a U-value of 1.8W/m$^2$K
- The old rooflights may have lost a large part of their light transmitting qualities – new rooflights will put daylight back into the building to make it a more pleasant place to work
- The additional daylight will mean the electric lights can be switched off creating further considerable energy savings and reduction in $CO_2$ emissions
- The new rooflights will be non-fragile making the roof a safer place should maintenance staff need to access the roof (but note that the opaque roof areas may also be fragile and remain so after the rooflights have been replaced)

## SUMMARY TO AD L2B

1. The requirement for any rooflight which is refurbished or replaced, and for new rooflights in extensions, is a U-value of 1.8W/m$^2$K when measured in the vertical plane. This means that rooflights will be triple skin as shown in AD L2B Table 3.

2. The norm for rooflight area in extensions will be up to 20% of the roof area as shown in AD L2B Table 2

3. It would be sensible for the designer to consider rooflight area carefully, to maximise the benefits of daylight on both energy use and the internal environment whilst avoiding solar overheating as outlined under AD L2A, although these considerations are not requirements of AD L2B

4. Repairs to individual rooflights, where the glazing is replaced within the existing frame, do not fall under the requirements of Part L.. Thus the repair can be like for like.

5. Where Consequential Improvements are required for the original building, replacing all the original single skin rooflights with new triple skin rooflights will be a very carbon and cost efficient solution with the added bonus that the people inside the building will greatly appreciate the better working conditions.

# FREQUENTLY ASKED QUESTIONS ON ROOFLIGHT REFURBISHMENT

1. **What am I required to do if replacing or repairing an individual broken rooflight?**

   Replacement of the glazing without replacing the frame of a rooflight is not regarded as replacement of the Controlled Fitting so does not come under the scope of Part L, and like for like replacement is permissible (see AD L2B para 4.23).

   This is also likely to be the situation if replacing a damaged outer sheet on an individual in-plane rooflight.

   Replacement of a whole rooflight including the frame is defined as replacement of a Controlled Fitting and the replacement rooflight would need to achieve an overall U-value of 1.8 $W/m^2K$ in compliance with ADL2B Table 3, so the replacement rooflight would have to be triple skin.

2. **What am I required to do if replacing degraded outer sheets of all the existing in-plane rooflights in a roof?**

   This is likely to be regarded as refurbishment rather than repair, and the upgraded rooflights would then need to achieve an overall U-value of 1.8 $W/m^2K$ in compliance with ADL2B Table 3, so the replacement rooflights would have to be triple skin.

3. **What should I do if I want to add additional rooflights to the existing building?**

   For an existing building the maximum area of rooflighting is 20% of the floor area as shown in AD L2B Table 2, and new rooflights may be added up to this maximum. Any new rooflights would need to achieve an overall U-value of 1.8 $W/m^2K$ in compliance with ADL2B Table 3, so the new rooflights would have to be triple skin. There is no requirement for the insulation level of the existing lights to be improved, unless they were replaced with new rooflights.

4. **I am extending the building. What control is there on any rooflights?**

   The extension may have up to 20% rooflights with a U-value of 1.8 $W/m^2K$ in compliance with ADL2B Table 3, so the rooflights in the extension would have to be triple skin. If the original building had rooflights to a greater area than 20%, then the extension may be designed to the same level of rooflights as the original building. Options with more design flexibility are shown in AD L2B paras 4.7-4.8.

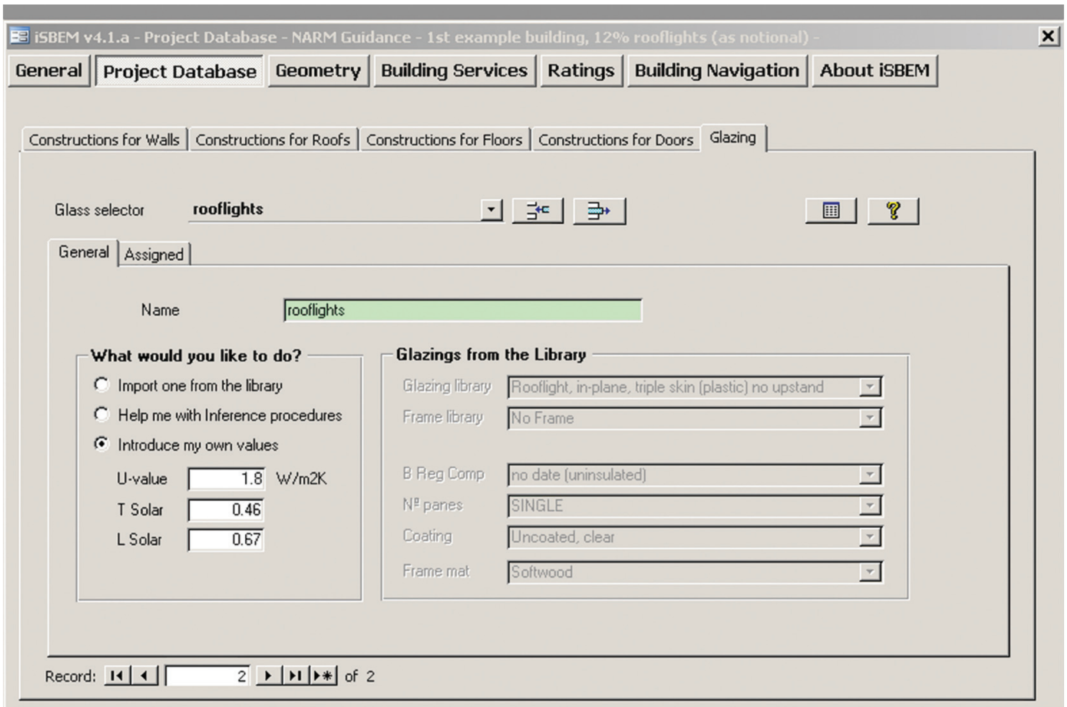
   Note that an extension may trigger a need for a “Consequential Improvement” on the original building, as detailed in the previous section of this document. If this is the case, upgrading the existing rooflights can be a very carbon and cost efficient solution with the added bonus that the people inside the building will greatly appreciate the better working conditions.

# **APPENDIX 1** HOW TO ENTER ROOFLIGHT DATA INTO ISBEM

All users of SBEM should be familiar with the SBEM User Manual and help facilities; this document does not attempt to explain how to use SBEM, but is intended to highlight how data specific to rooflights should be entered into SBEM, and key points to be aware of.

## (a) rooflight data

For each type of rooflight which are going to be used on any particular building, the main thermal, light and solar transmission properties should be entered into SBEM in the “Project database” form, under the “Glazing” tab. It is recommended that the user uses the “Introduce my own values” option, and enters data available from rooflight manufacturers, as shown below:




Properties which should be entered for the actual rooflights are:

- U-value (in W/m²K) as measured in the vertical plane
- T-solar
- L-solar

**U-value**
This value should include allowance for any heat loss through glazing bars and frame, not just a centre pane value and should be based on the developed area i.e. the Ud-value as defined in NARM Technical Guidance NTD2.

This value should be less than the limiting values in AD L2A and L2B - for new build it should be less than 2.2, and for refurbishment or extensions it should be less than 1.8

Note that out-of-plane rooflights are generally mounted on a kerb or upstand, which may be manufactured on site, or supplied as part of the rooflight.

Where kerbs are supplied with the rooflight, they should be regarded as part of the rooflight, and the Ud-value for both the rooflight alone, and the rooflight-and-kerb assembly should be calculated in accordance with NARM Guidance Note NTD2. Both values must achieve the relevant limiting value (2.2 or 1.8 W/m$^2$K), and the value for the the rooflight-and-kerb assembly should be entered into SBEM.

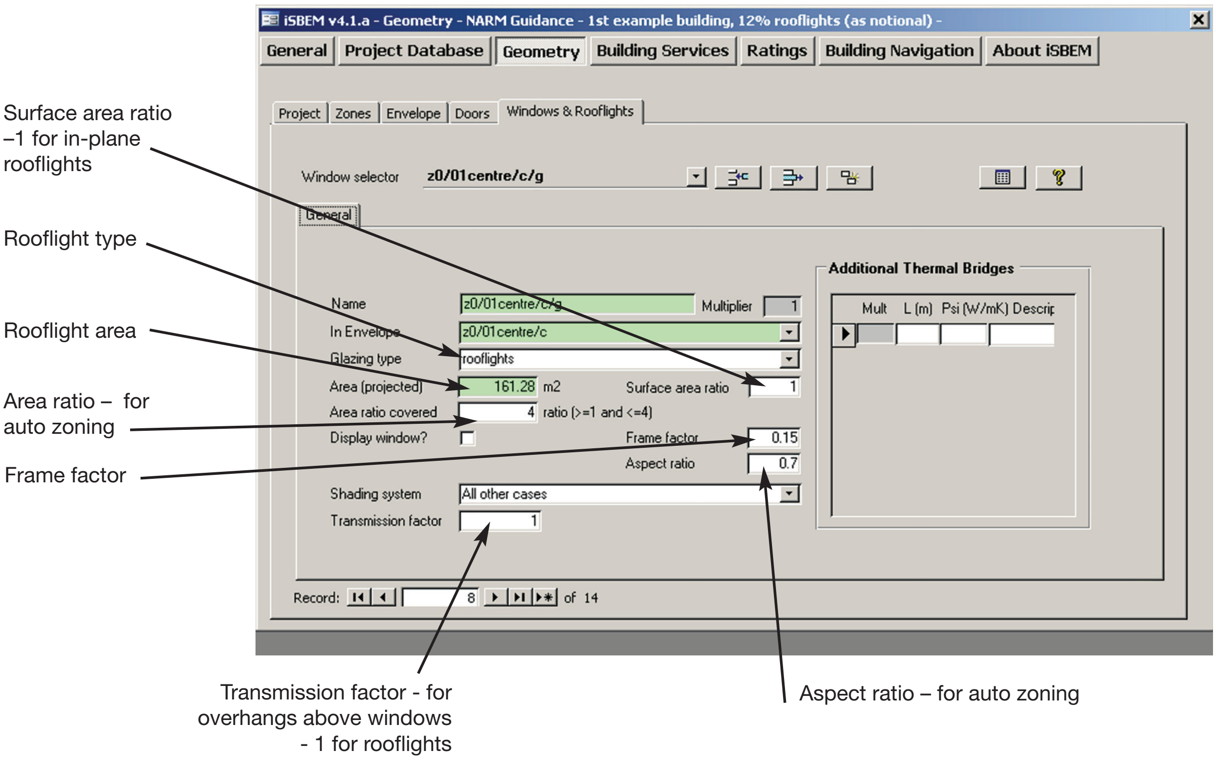
Where kerbs are existing or manufactured on site, they can either be regarded as part of the rooflight and analysed as above, or regarded as part of the roof in which case they should meet the requirements for the roof, or where less well insulated treated as a thermal bridge.

**T-solar**
T-solar is the total solar transmittance, or the G-value of the actual rooflight. This is used only for solar overheating calculations (not for $CO_2$ emission calculations)

**L-solar**
L-solar is the light transmission of the actual rooflight. This is used only for $CO_2$ emission calculations to determine whether the actual building achieves the TER (not for solar overheating calculations)

## (b) rooflight geometry

Once all the rooflight properties have been entered in the “Project Database” form, the geometry of each rooflight should be entered in the “Geometry” form, under the “Windows and Rooflights” tab:



Properties which should be entered for each actual rooflights are:

- In Envelope
- Glazing Type
- Area (projected)
- Shading System
- Transmission factor
- Surface Area ratio
- Frame factor
- Area ratio covered
- Aspect ratio

**In Envelope**
This simply defines the specific element of the building that the rooflight is positioned in

**Glazing Type**
This refers to the description of the relevant rooflight type as already entered into the Project database form, and ensures the correct thermal, light and solar transmission properties are used

**Area (projected)**
This is the projected area of the actual rooflight (not the developed area as defined in NARM NTD2 which is used for U-value calculations), and is the area used for illumination and solar gain calculations

**Shading System**
This relates to shading systems such as blinds which rarely applies to rooflights, so this should usually be set "All other cases"

**Transmission factor**
This is related to loss of transmission due to shading eg from overhangs above windows, which rarely applies to rooflights so this should usually be set to 1

**Surface Area ratio**
This is the ratio of the developed (ie surface) area of the rooflight (as defined in NARM Guidance Note NTD2, and used to calculate the $U_d$-value) to the projected area. By definition, this is also the ratio of the true U-value to the $U_d$-value.

If the surface area ratio for a particular rooflight is not available, an acceptable alternative is to enter the true U-value (based on projected area) into the Project Database form then enter a value of 1 as surface area ratio, as this will give the correct heat loss.

However, if the U-value entered into the Project Database form is a $U_d$-value based on a developed area that is greater than the projected area (giving a $U_d$-value which is lower than the U-value), then the surface area ratio must be entered correctly.

Note that for in-plane rooflights, because the effect of profile can affect developed area dramatically, the U-value quoted is usually the true U-value rather than a $U_d$-value, and a surface area ratio of 1 should therefore be used.

For out-of-plane rooflights, it is more common to quote the $U_d$-value (for comparison to the limiting values in AD L2A and L2B) and the corresponding surface area ratio must be entered.

**Frame factor**
This is the percentage of the rooflight area which is not glazed

For in-plane rooflights, this is the proportion of the area covered by opaque sheet at laps (side and end) and purlins.

For out-of-plane rooflights, this includes any glazing bars, or effective reduction in area due to splayed kerbs.

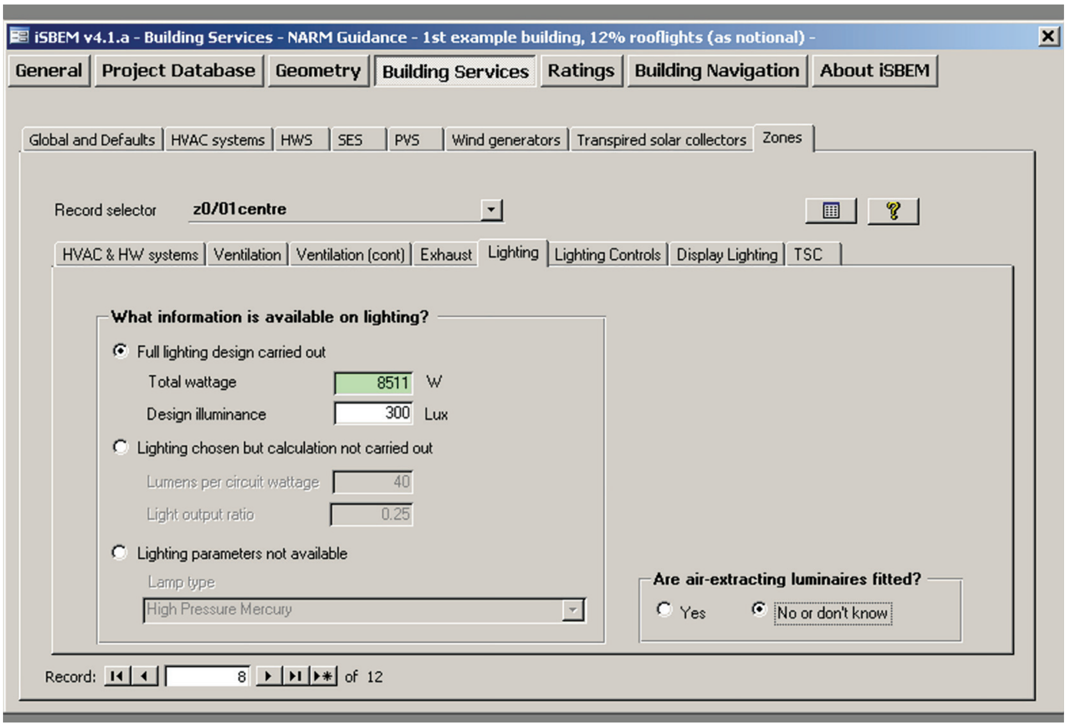
**Area ratio covered**
This is a factor used when automatic daylight zoning is selected, but SBEM does not now subdivide rooflit zones, so this parameter is no longer relevant for rooflights. It referred to the ratio of the floor area illuminated by rooflights divided by the rooflight area.

**Aspect ratio**
This is also a factor only used when automatic daylight zoning is used, but SBEM does not now subdivide rooflit zones, so this parameter is no longer relevant for rooflights. It defined the ratio of the length: width of the rooflight which SBEM assumes.

## (c) Lighting system

Details of the lighting system are entered in the "Building Services" form, under the "zones" tab, and the "lighting (general)" subtab.

Generally, details for a full lighting design have to be entered for each zone:



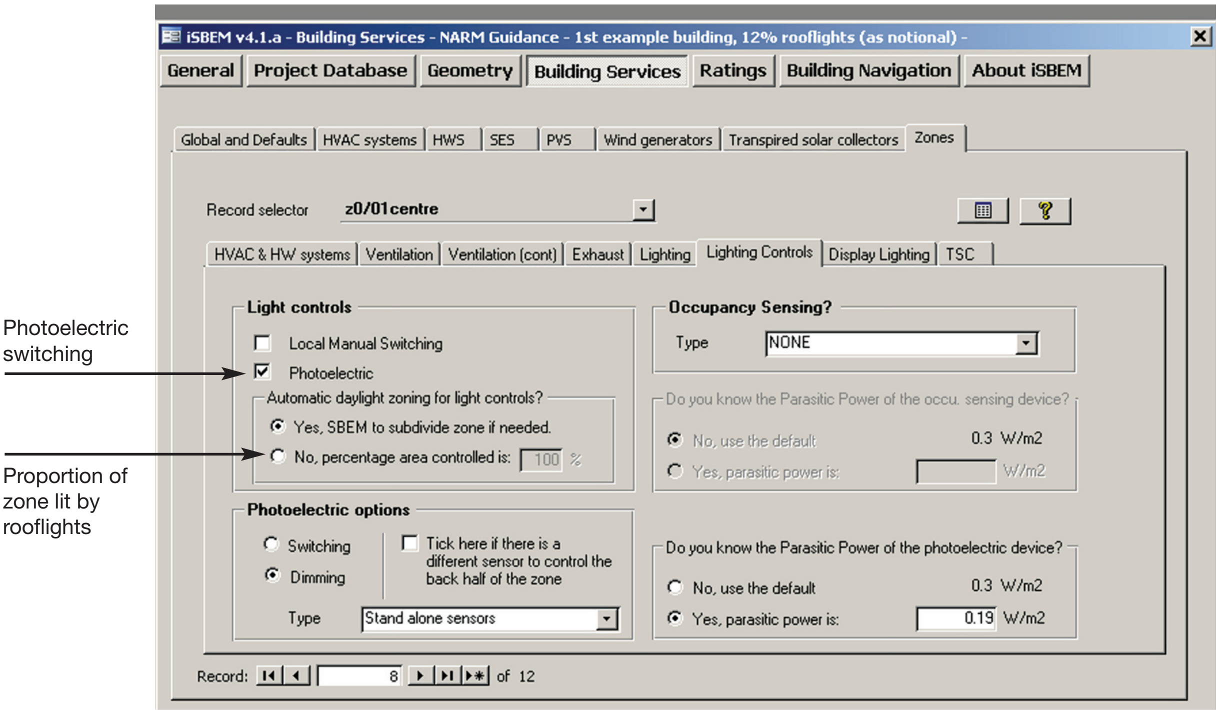

The wattage of the lights in each zone and the design illuminance they are designed to achieve have to be entered into SBEM: the latter is the illuminance which the lighting system is expected to achieve not the design illuminance for the zone, which is fixed in the SBEM database, depending on the activity in the zone. Entering a higher figure does not imply a brighter internal environment, it just means a more efficient lighting system has been defined.

Note that details of the efficiency of lighting systems assumed in the Notional Building are shown on page 18 of the National Calculation methodology modelling guide 2010. It assumes lighting with an efficacy of 55 luminaire lumens per circuit-watt, and Equation 7 defines the actual power density (ie the watts per 100lux), which depends on the zone geometry.

## (d) Lighting control system

It is essential that correct control of the artificial lighting system is defined (as detailed in Graph 2 of this report): without automatic control of the lighting system SBEM assumes the lights stay on all the time regardless of available daylight, so that in the example building, $CO_2$ emissions from the lighting system alone are higher than the total permissible $CO_2$ emissions from all aspects of operation, having a dramatic negative impact on overall performance of the building and making compliance extremely difficult.

Details of the lighting control system are entered in the "Building Services" form, under the "zones" tab, and the "lighting (Controls)" subtab.




Properties which should be entered for the lighting control system in every zone are:

- Light Controls
- Automatic daylight zoning for light controls
- Photoelectric options
- Occupancy sensing
- Parasitic power

**Light Controls**
The "photoelectric" box should always be ticked if the actual building has automatic control of the lighting system – and for many buildings this will be critical in order to achieve compliance.

Note that the Notional Building includes photoelectric contol of the lighting system for rooflit zones.

**Automatic daylight zoning for light controls**
SBEM does not now subdivide zones for rooflit areas, but assumes rooflights illuminate a zone evenly.

For clarity, it is recommended to select “No, percentage controlled is” and enter 100% - this is the percentage of the area of a zone that is illuminated by the rooflights. If the rooflights are not distributed evenly but only illuminate part of a zone, an appropriately lower figure should be entered here.

**Photoelectric options**
The “switching” (ie on-off control) or “dimming” (ie proportional) option can be selected here, depending on the type of lighting control system being specified for the actual building.

Graphs 1 and 2 of this document show the effect of this change – dimming controls give greater saving in energy consumption of the lighting sytem.

Note that the Notional Building includes dimming contol of the lighting system for rooflit zones.

**Parasitic power**
This is the energy used by the lighting sensors and control system even when the lights themselves are turned off, and will depend on the specification of the lighting control system to be used in the actual building

Note that the Notional Building assumes parasitic power to be the lesser of 3% of the installed lighting load, or 3 $W/m^2$.

## **APPENDIX 2** THE DE MONTFORT RESEARCH

Assessing the overall impact of rooflights and glazing on the energy efficiency of a building is a complex task, and detailed research has been carried out by The Institute of Energy and Sustainable Development at De Montfort University.

Consideration was given to the difference in insulation value between rooflights and 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 rooflight.

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, assessed on an hour-by-hour basis for a whole year. It analysed the heat flow and illuminance through an entire roof including rooflights covering between 0 and 20% of the roof area.

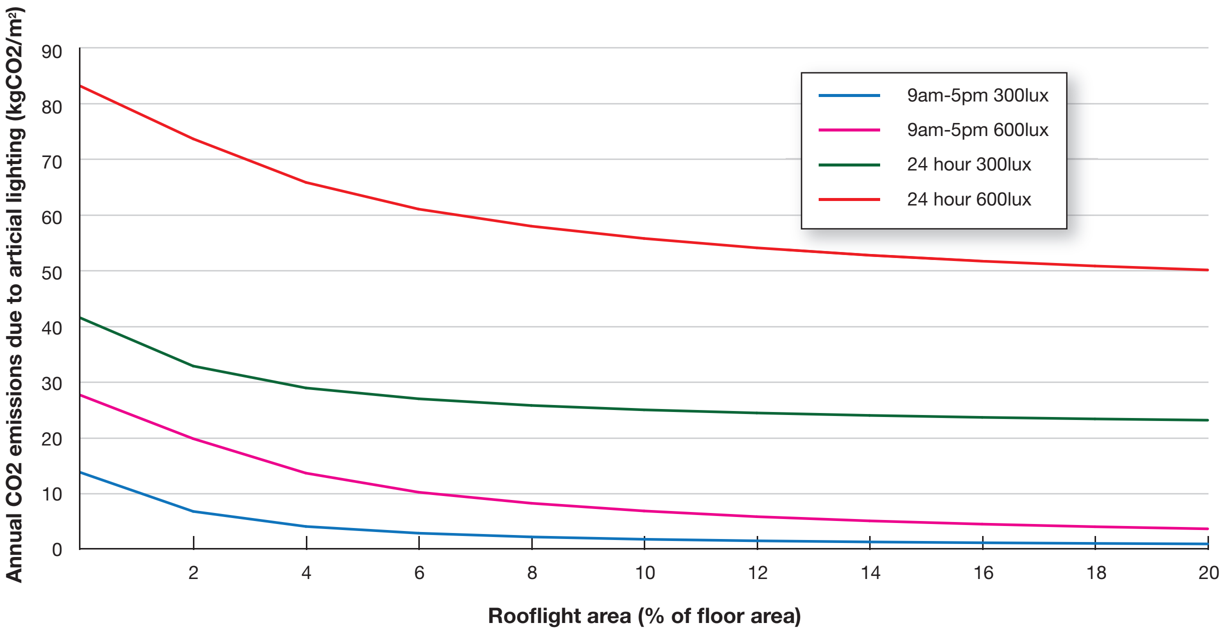
Thermal analysis used 'EnergyPlus' software, widely recognised as the most accurate available for this type of work, and significantly more accurate than the SBEM software used for Part L compliance. This took account of the different insulation values of the roof and rooflights, differing internal and external temperatures, radiant heat on the roof, and included the beneficial effect of passive solar gain through the rooflights. Results show the effect of rooflight area on heat flow through the whole roof, which is the only heating load affected by rooflight area: it did not assess heat loss through the rest of the building where there are many more variables.

Illumination levels inside a building for different rooflight areas and types were also calculated. The design illumination level, and efficiency of the lighting and lighting control systems define the energy needed to provide artificial lighting. The results show the effect of rooflight area on annual lighting system energy use and allow the effects of different patterns of building use (eg design illumination levels and hours of use) to be assessed.

Data for the energy used by heating and lighting systems was combined and converted into equivalent $CO_2$ emissions to show the overall effect that rooflight area has on total $CO_2$ emissions.

The findings prove conclusively that rooflights provide an overall energy benefit - with the level of that benefit depending on many factors, particularly the area of rooflights installed, design

**Figure 1:** Effect of rooflight area on CO2 emissions due to artificial lighting system



illumination level, type of artificial lighting control used and the pattern (hours) of building use.

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. The illustrations below use 300 and 600 lux. A light level of 300 lux is moderate giving adequate lighting for general activities and circulation spaces such as packaging areas. A light level of 600 lux would be required where a degree of colour judgement was required or more detailed visual tasks were taking place such as in many retail and office environments, or product assembly areas.

Figure 1 clearly shows that the greater the rooflight area, the less artificial light is required - and hence 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 saving which can be offered by increasing rooflight area.

For example, with 300 lux illumination and 9am-5pm use, there is a reduction in lighting system's $CO_2$ emissions from 14 to 1 $kgCO_2/m^2$ as rooflight area increases from 0 to 20%. As hours of use increase, the overall energy use increases and so does the saving: a saving of 18 $kgCO_2/m^2$ per annum is made for 24 hour use. At an illumination level of 600 lux, an increase in rooflight area from 0 to 20% results in a saving of 25 $kgCO_2/m^2$ for 9am-5pm use and up to 33 $kgCO_2/m^2$ for 24 hour use.

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

**Figure 2:** Effect of rooflight area on CO2 emissions - 9am-5pm

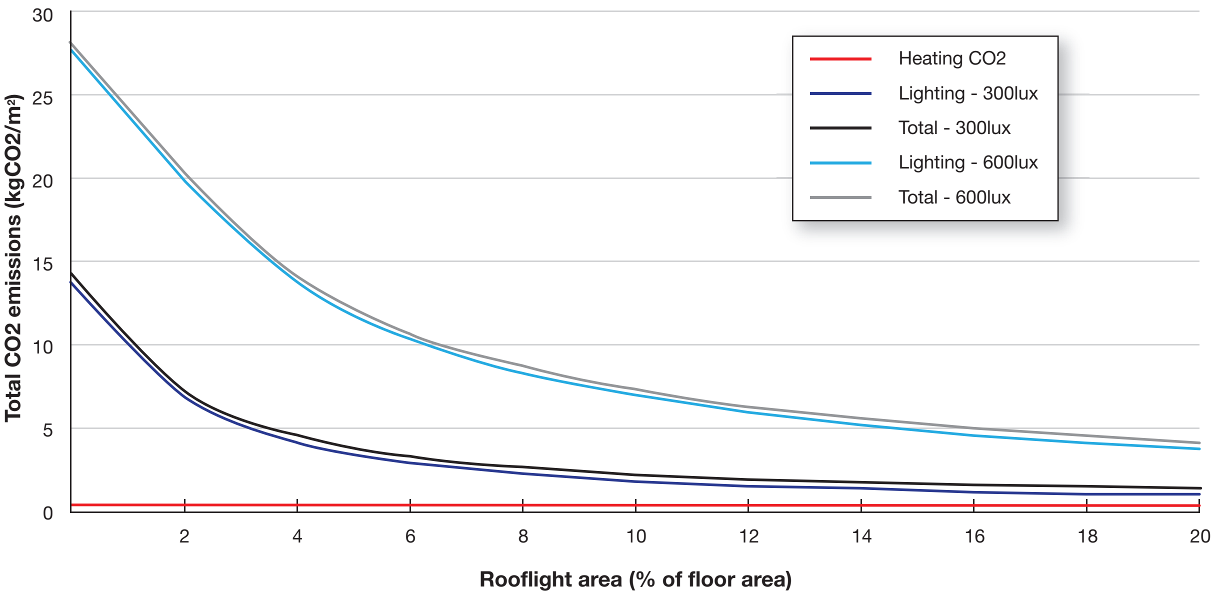



Figure 2 shows the overall effect of rooflight area on $CO_2$ emissions for a building used 9am-5pm. The red line shows the effect on emissions due to the energy use of the heating system for heat loss through the roof (only), the blue lines show the effects on emissions due to the energy use of the lighting system for both 300 and 600 lux (as shown in Figure 1), and the black line shows the sum total of heating and lighting.

Note that an increase in rooflight area (at least within the range 0 to 20%) will result in a dramatic reduction in total $CO_2$ emissions. Based on traditional considerations of insulation value alone, it may have been expected that the heating energy requirement would increase as rooflight area increased, but the research proves that for a building occupied primarily during the day this is not the case. Passive solar gain through the rooflights actually balances the insulation value, so heating requirements are barely affected and by far the dominant effect is the decreasing requirement for artificial light as rooflight area is increased.

The worst case scenario for rooflights 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 rooflights still provide a very significant energy benefit.

**Figure 3:** Effect of rooflight area on CO2 emissions - 24 hour

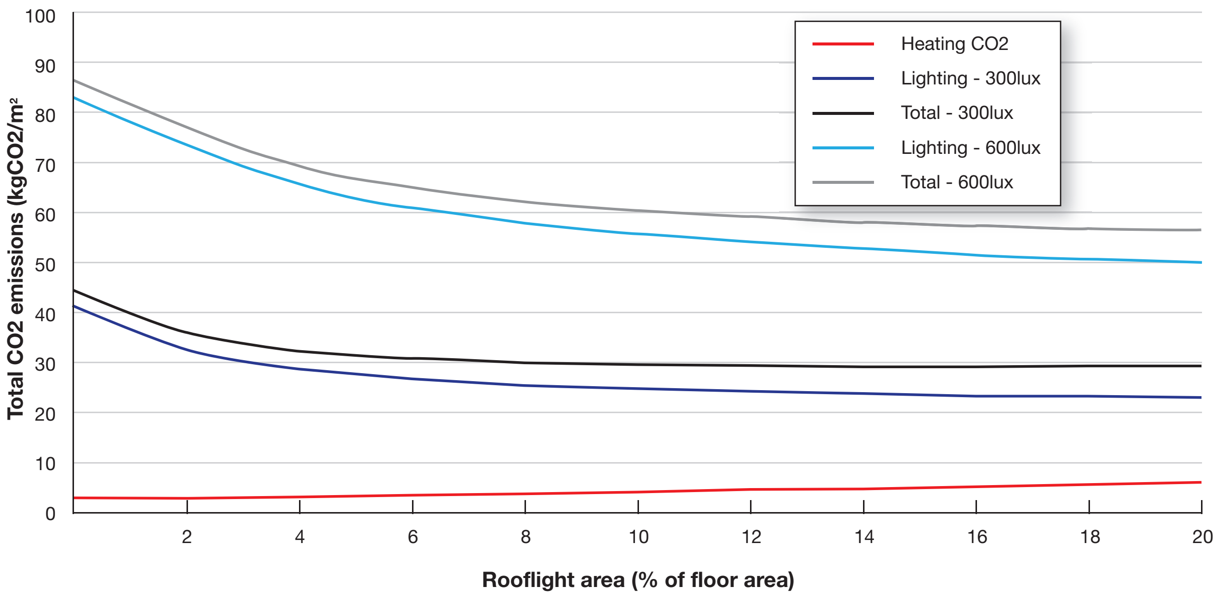



Figure 3 shows the overall effect of rooflight area on $CO_2$ emissions for a building used 24 hours a day. The red line again represents the heating requirement - and in this case it can be seen that the total heat loss through the whole roof approximately doubles as rooflight area increases from 0 to 20% since at night there is increased heat loss through the rooflights which is not balanced by any solar gain. However, in most cases, the savings in lighting energy requirement still far more than outweigh this.

With a lighting requirement of 600 lux the total energy use continues to drop as the rooflight area increases, up to 20%. Where the lighting requirement is a relatively low 300 lux, at rooflight areas up to approximately 14%, the savings in lighting energy are the dominant effect and total $CO_2$ emissions fall as rooflight area increases; at higher rooflight areas the increase in heating requirement and decrease in lighting requirement are approximately equal, so the overall $CO_2$ emissions then remain constant up to a rooflight area of 20%.

**Conclusions of the De Montfort University Research**

These examples look at 2 illumination levels (300 and 600lux) and 2 patterns of use (9am-5pm and 24 hour), clearly demonstrating that where use of rooflights is appropriate:

- rooflights always make a positive contribution: omission of rooflights gives a very significant increase in $CO_2$ emissions
- in most buildings, savings continue to be achieved as rooflight area is increased up to 20%
- in buildings used primarily during daylit hours:
    - o the savings are significant as rooflight area increases up to 15% in all cases
    - o where illumination levels are relatively low, the further savings as rooflight area is increased above 15% are relatively minor
    - o there are significant further savings as rooflight area increases up to 20% at higher illumination levels
- in buildings used 24 hours a day:
    - o there are savings as rooflight area increases up to 15% in all cases
    - o where illumination levels are relatively low, the savings as rooflight area is increased from 10% to 15% are relatively minor, with very slight increases in $CO_2$ emissions as area increases further, to 20%
    - o at higher illumination levels, there are savings as rooflight area is increased up to 20%, but the further savings as rooflight area is increased above 15% are relatively minor

In summary, these results show that rooflight area equal to 15% - 20% of floor area may be a useful approximation of the optimum rooflight area. In some buildings there may be benefit from slightly higher rooflight areas, and occasionally the optimum may be slightly lower, so there may sometimes be small further gains available from adjustments in rooflight area - but in almost all cases a rooflight area of 15% - 20% will achieve almost all of the available savings in overall energy use and $CO_2$ emissions.

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Web: www.palram.com

**Reichhold UK Ltd**
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Web: www.reichhold.com

**The Rooflight Company**
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