NATIONAL ASSOCIATION OF ROOFLIGHT MANUFACTURERS

DESIGNING WITH ROOFLIGHTS : SUPPORTING THE GUIDANCE IN AD L2A & AD L2B (2006)

Issue 1 - November 2006

Note: it is expected that there will be on going updates to AD L2A & 2B over the next 2 years. As this happens, this NARM Guidance Document will be amended as necessary with a new issue number and date. The latest version will always be available to download from the NARM website www.rooflights.org This issue relates to the Approved Documents issued by ODPM/DCLG in April 2006 and the SBEM results shown are from v1.2.a

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DESIGNING WITH ROOFLIGHTS : SUPPORTING THE GUIDANCE IN AD L2A & AD L2B (2006)

Scope

- This document gives guidance on the use of natural daylight via rooflights to provide compliance with the energy efficiency requirements of Building Regulations Approved Document L2 – Conservation of Fuel and Power for Buildings other than Dwellings as amended in 2006
- This document covers both New Work (L2A) and Refurbishment and Extensions (L2B) and should be read in conjunction with the Approved Documents AD L2A and AD L2B issued by the Office of the Deputy Prime Minister (ODPM)*, to which reference will be made
- Reference will be made to the Simplified Building Energy Model (SBEM) software (which is the approved calculation tool referenced by AD L2A para 20a 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.
- This Guidance does not cover Dwellings. (L1)
- It 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 CO_2 emissions. It shows that as rooflight area is increased up to 20% of the floor area, carbon dioxide emissions will generally decrease, as the contribution of natural daylight through rooflights replaces the need for artificial lighting
- It 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 of natural daylighting into buildings
- Buildings that fall outside the requirements of Part L, e.g. unheated agricultural buildings, are not covered by this document
- Via examples using SBEM, this document will demonstrate the need to consider the total lighting demand for a building and to utilise 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
- Note that Dwellings relate to self contained units only. Rooms for Residential Purposes are not dwellings and come under the Guidance of AD L2A & B

** Note that the reference to AD L2A &B is that edition published by the ODPM in April 2006. It is understood that this edition has errors and will be corrected later this year. Also note that from April 2006 the documents became the responsibility of the Department for Communities & Local Government (DCLG). It should also be noted that the Approved Documents are Guidance Documents and are not mandatory, however the detail in the Documents will provide solutions that will give compliance with Schedule 1 and Regulation 7 of the Building Regulations 2000 England and Wales.*

Introduction

The new Building Regulations Part L 2006, designed to save energy and power consumption in buildings, is part of an on going legislative programme by the Government with further updates planned over the next 20 years to create a long term building stock that will generate an ever decreasing release of carbon dioxide (CO_2) into the atmosphere.

Previous Part L legislation has concentrated on the fabric and assembly detailing of the building. Part L 2006 now considers the energy used by all the systems required to operate the building, including:

- Heating
- Cooling
- Artificial lighting
- Domestic hot water

It continues to consider the fabric and assembly details of the building, which obviously impact on the energy use of the heating and other systems, but also considers the type and efficiency of the various building services to establish the total energy needed to operate the building, which is considered in terms of the CO_2 emitted to the atmosphere whilst generating this energy. This has become known as the building's "carbon footprint".

The interaction of building fabric and services requires a fundamental rethink to the design parameters of buildings. A good example of this is the consideration of rooflights to buildings. To allow daylight to pass through the rooflights, they cannot be filled with opaque insulating materials and thus rooflight areas are less insulated than the opaque area of the roof. In the past this has meant that reducing the rooflight area would improve the insulation quality of the building. Such decisions did not consider the impact of turning on the electric light to replace the reduced or lost natural daylight. The new legislation will now consider not only the energy impact of designing with rooflights to provide natural daylight but will weigh this energy cost against the energy cost of providing artificial electric lighting.

The other key fundamental change to Part L 2006 is that energy compliance will now be done by approved software such as the Simplified Building Energy Model (SBEM) that can be obtained from the DCLG. The computer program will consider the data for the complete building. Every piece of data will have a relevance to the energy consumption of the building and have an effect on whether or not the building (based on that defined in the Part L 2002 regulations) will be compliant. To comply, a stated reduction in CO_2 emissions, when compared to a Notional Building (based on that defined in the Part L 2002 regulations) must be achieved. In the case of rooflights, the Notional Building includes 20% rooflight area. This Document will show worked examples of SBEM using different levels of rooflighting and demonstrate that if the rooflight area is reduced below 20% then the carbon footprint will often increase.

Designing with Rooflights to Save Energy

New research proves conclusively that rooflights can save energy in many applications. 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.

Design parameters for the building, such as temperature set point, hours of occupancy, and internal gains, can all alter the effect that rooflight area can have on the total energy requirements of heating, cooling and artificial lighting systems. 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.

De Montfort University Research

The Institute of Energy & Sustainable Development at Leicester's De Montfort University 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. 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.

In order to assess all aspects of energy use, the new regulations require computer modelling of all new buildings. This computer model, the Simplified Building Energy Method (SBEM), uses the same principles as De Montfort University (DMU) research, and so also recognises the contribution to energy saving and reduction in CO_2 emissions which are offered by 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 SBEM software and the conclusions of the DMU work shows that:

- 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 daylight hours:
  - the savings are significant as rooflight area increases up to 15% in all cases
  - where illumination levels are relatively low, the further savings as rooflight area is increased above 15% are relatively minor
  - there are significant further savings as rooflight area increases up to 20% at higher illumination levels
- in buildings used 24 hours a day:
  - there are savings as rooflight area increases up to 15% in all cases
  - where illumination levels are relatively low, the savings as rooflight area is increased from10% to 15% are relatively minor, with very slight increases in CO_2 emissions as area increases further, to 20%
  - 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

Rooflight area of 15% - 20% of floor area may therefore be a useful approximation of the optimum rooflight area. In most buildings the optimum will be around 20% of floor area. In many cases, a reduced area of 15%, whilst less than optimum, will give most of the available savings in overall energy use and CO_2 emissions.

Further detail on the work carried out by DMU on the reduction of the energy consumption on buildings as the rooflight area is increased to 20% are shown in Appendix 1 to this document. The graphs to this work demonstrate the amount of energy that is required to provide artificial lighting and clearly show that natural daylight within the building will provide the opportunity to make considerable savings on the energy demand.

Note the DMU results are compiled from Energy Plus software. This software is highly sophisticated and complicated to use. The data that has been installed into SBEM is assembled by the Building Research Establishment (BRE). This data is based on the same premise and provides output showing similar results and trends.

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" requirement.

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 fuels 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 pleasant environment

The DMU work highlighted 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 usage. This document does not detail all the options that are available and such information should be obtained from a good artificial lighting specialist. However the research carried out by DMU on lighting control has been summarised in Appendix 2 of this document.

AD L2A New Buildings Other Than Dwellings

Compliance with AD L2A would be demonstrated by meeting 5 separate criteria (see AD L2A para7)
- criterion 1: the calculated CO_2 emissions must meet a defined target
- criterion 2: the performance of the building fabric (and systems) must meet design limits - see page 8
- criterion 3: there must be passive measures to limit solar gain - see page 8
- criterion 4: the as-built building must be consistent with the designed building (see AD L2A Paras 66-81)
- criterion 5: there is provision to operate the building in an energy efficient way (see AD L2A Paras 82-84)

This document covers the effect of rooflights on the first 3 criteria. Rooflights have no specific effect on the latter 2 criteria, which are therefore outside the scope of this document.

Criterion 1: Calculated CO_2 emissions rate (see AD L2A paras 18- 32)

The calculated CO_2 emissions rate for the actual building (the building emission rate, BER) must not be greater than the target emission rate (TER).

The TER is a given percentage improvement over the CO_2 emission rate of a notional building, calculated using the Simplified Building Energy Model (SBEM) or other approved software tool.

The notional building (defined in AD L2A para22) is the same size and shape as the actual building, but with fixed performance of both building fabric and services. Each element of the building fabric has the same performance as the notional building defined in Part L 2002 (Tables 1 & 2), which includes 20% rooflights, with a U-Value of 2.2 W/m²K.

The improvement required over the performance of the notional building (defined in AD L2A para 23) is typically 23.5% for naturally ventilated, or 28% for mechanically ventilated / air conditioned buildings, respectively.

The BER is the CO_2 emission rate (calculated using the same software tool as the TER) for the actual building.

Simplified Building Energy Model (SBEM)

SBEM data entry – generic rooflight properties

Appendix 3 gives full details of how data for rooflights should be entered into SBEM.

The generic properties of the rooflights are selected by either:
- selecting an option from the standard SBEM library, which includes various rooflight types (eg in-plane, dome/pyramid, barrel vault, panel glazing and architectural skylights), each of which can be entered as single, double, triple or better insulated variants
- entering properties for the rooflight directly - the U-value, L-solar, and T-solar values

Note that single and double skin options should only be used where existing buildings are being analysed: for new build, or extensions, all rooflights should be triple skin or better to achieve a weighted average U-value of 2.2 W/m²K as shown in AD L2A Table 4. Criterion 2 (see page 8) sets detailed U value requirements for Rooflights.

Data entered for out-of-plane rooflights must account for the effects of any glazing bars and kerbs. Appendix 3 gives full detail on how to do this.

SBEM data entry – specific rooflight details

Once generic details have been completed for any rooflight type(s) being used on the project, data for each individual rooflight application needs to be entered, including:
- the rooflight area (in each zone of the building)
- the surface area ratio (ie the ratio of rooflight area: daylight area which varies typically between 1.0 and 1.4 depending on rooflight type)
- the transmission factor, needs to be amended from the default value to 1.0 since this factor accounts for any shading (from overhangs etc) which doesn't apply to rooflights

It is critical that information for artificial lighting systems and lighting control systems is also entered correctly, since these are essential in order to achieve the reductions in CO_2 emissions which can be offered by the correct use of natural daylighting.

SBEM results

SBEM generally shows that if rooflight area is reduced from the 20% area defined in the notional building, then overall CO_2 emissions increase: rooflight areas up to 20% minimise CO_2 emissions, give best SBEM results and help meet criterion 1 of AD L2A.

SBEM has been used to analyse two example buildings to demonstrate this:
- example 1: a large open span metal clad building, fitted with varying areas of in-plane rooflights
- example 2: the 'example building' used in the tutorial published with SBEM (with heating fuel altered to natural gas, to give a true reflection of heating requirement on CO_2 emissions). This building was modelled without rooflights (as shown in the tutorial) and then with varying areas of individual dome rooflights

Full details of both buildings are shown in Appendix 4.

The graphs in Figures 1-3 show the effects of altering rooflight area and rooflight U-value on overall CO_2 emissions, and also show CO_2 emissions due to heating and lighting requirements individually. Full details of the SBEM results, as summarised in these graphs, are shown in Appendix 5.

Figure 1: Effect of Rooflight area on CO_2 emissions for first example building

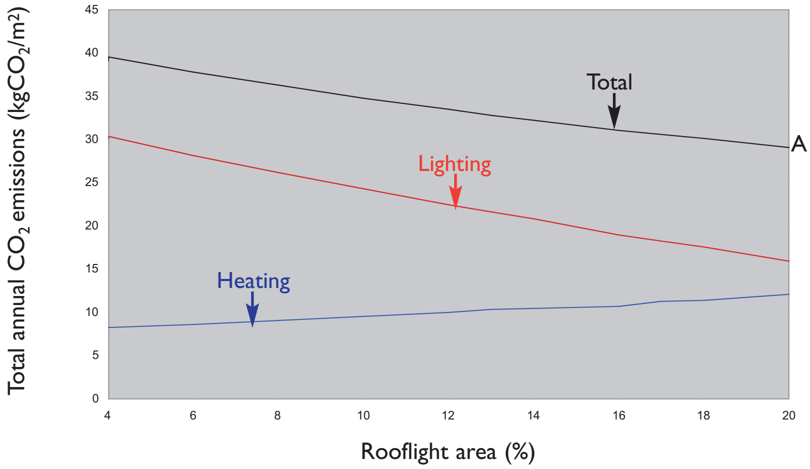


Figure 2: CO_2 emissions compared to notional building for first example building

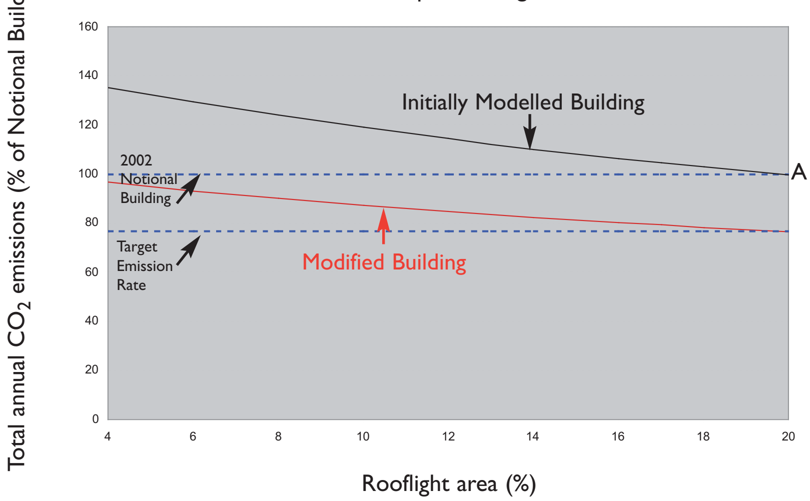


Figure 1 shows the overall CO_2 emissions when the first example building was modelled without rooflights, and with rooflight areas varying up to 20% (as assumed in the notional building) to demonstrate the effect of varying the rooflight area.

It also shows the SBEM calculation of energy used by heating and lighting systems separately (converted to CO_2 emissions using the conversion factors shown in AD L2A Table 2 – shown in Appendix 5).

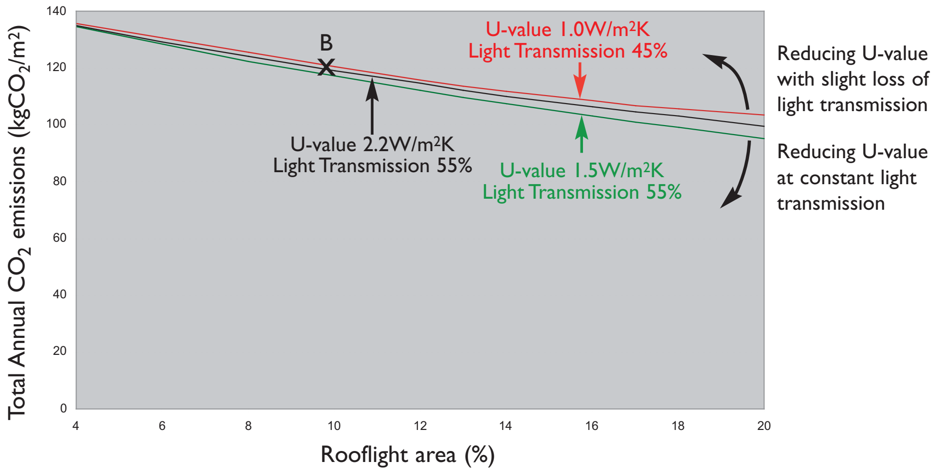
This graph clearly shows that rooflights offer a significant saving in overall CO_2 emissions, and thus make a major contribution towards meeting the target CO_2 savings of AD L2A.

As rooflight area increases to 20%, overall CO_2 emissions continue to fall; in this example overall CO_2 emissions are 20% higher with 10% rooflights or over 35% higher without rooflights than they are with 20% rooflight area.

SBEM shows that, for this example, the CO_2 emissions for the notional building are 29.23kg CO_2/m^2 per annum (see Appendix 5); the overall CO_2 emissions shown in Figure 1 can also be expressed as a percentage of this figure, and are shown in this way in Figure 2, which also shows the performance of the notional building (100%) and the TER (23.5% saving).

The building initially modelled (with 20% rooflight area, U-value 2.2W/m²K) has been modelled as closely as possible on a "2002 notional building". The actual CO_2 emissions (BER) of this building, with 20% rooflight area (as in the 2002 notional building) are therefore equal to (100% of) the notional building. This is shown by point A on figures 1&2, whilst the black lines show the increase in CO_2 emissions if rooflight area is reduced, illustrating the same increase in CO_2 emissions (to over 135%) as rooflight area is decreased.

Figure 3: Effect of rooflight U-value and light transmission for first example building



Buildings with improved performance

Significant improvement to the performance of the building would be required to achieve the TER (in this case, a saving of 23.5%). There are many ways of achieving this, such as improvements to lighting, heating and control systems, elemental U-values, air permeability, thermal bridging or use of renewable energy such as photovoltaics, solar energy systems, wind generators or solar walls.

The red line in Figure 2 shows results for an "improved" building where a selection of these improvements have been made, to achieve the TER of 76.5% when fitted with 20% rooflights.

These curves show the same trend as rooflight area is decreased for both the original and improved buildings: as rooflight area is decreased below 20%, so CO_2 emissions increase.

Whilst the target improvement set by AD L2A for a building with 20% rooflights may be 23.5% (ie a target of 76.5% of the notional building), if rooflights are omitted the starting point is more than 35% greater than the Notional Building and therefore an improvement of over 45% is required from this higher starting point. Similarly, if 10% rooflights are fitted, a 35% rather than 23.5% improvement would be required to achieve the TER.

Effect of U-value and light transmission

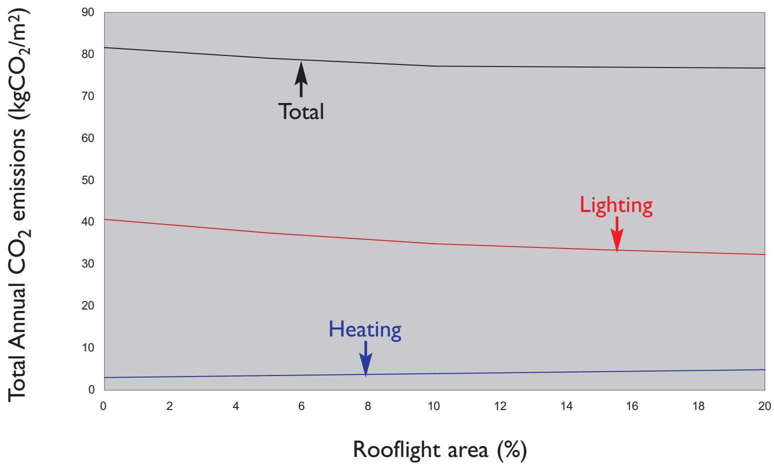
Better insulation of rooflights can offer further savings in CO_2 particularly at higher rooflight areas, as this can reduce energy use of the heating system, but this effect is secondary to factors which affect energy use of the lighting system - rooflight area and light transmission through the rooflight.

This is illustrated by Figure 3, which shows the effect of varying rooflight insulation value and light transmission. The black line shows an SBEM analysis with rooflights with a U-value of 2.2W/m²K (the minimum allowable insulation value as shown in AD L2A Table 4), and an overall light transmission of 55%; the green line shows analysis for the same building with rooflights with a significantly improved U-value of 1.5W/m²K (with unchanged light transmission).

This shows that in comparison to 10% rooflights with a U-value of 2.2W/m²K (point B on the black line), the following savings in CO_2 emissions can be achieved:

- 9% by increasing rooflight area to 15%
- 16% by increasing rooflight area to 20% (at 2.2 U-value)
- 1.5% by improving U-value to 1.5W/m²K (at 10% rooflight area)
- 20% by increasing rooflight area to 20% and improving U-value to 1.5W/m²K

Figure 4: Effect of rooflight area on CO_2 emissions for second example building (SBEM tutorial)



An increase in rooflight area and an improvement in rooflight insulation can both offer a saving in CO_2 emissions - but it is much more effective to increase the area of rooflight with a given U-value than it is to increase the insulation of a rooflight at a given area.

Light transmission through the rooflight has a similar effect as rooflight area, since both parameters directly affect amount of light passing through the rooflight and hence energy use of the lighting system: light transmission through the rooflight is also more significant than U-value.

Care should therefore be exercised before focussing on rooflight U-values, since very well insulated (low U-value) rooflights often give slightly lower light transmission, which counters the effect of the lower U-value, reducing or even negating the expected saving in overall CO_2 emissions.

For example, the red line in Figure 3 shows the SBEM analysis if rooflight U-value is reduced further (to 1.0W/m^2K) but this is accompanied by a slight reduction in light transmission (to 45% overall) as is likely in practice. It shows the overall CO_2 emissions are higher than those achieved with rooflights with a U-value of 2.2 W/m^2K and light transmission of 55%: the small change in light transmission has a greater effect than the large improvement in rooflight insulation.

Second Example Building

Figure 4 shows results for the second example building; this is exactly as defined in the SBEM tutorial.

This building has been designed to significantly better standards than a 2002 notional building; even without rooflights, it achieved results where the BER was 69% of the notional building, thus achieving the TER of 72%.

However, when rooflights were introduced, even in this multistorey building where they can obviously not have as great an impact, the contribution is still positive: overall CO_2 emissions without rooflights are 6.5% higher than when 20% rooflights are fitted. Separate checks are required to ensure Criterion 3 is also met: see page 10.

Summary of Criterion 1:

It is clear that in most building types, use of natural daylight in conjunction with well designed lighting and lighting control systems will reduce the energy consumption of artificial lighting systems. This will usually result in a reduction in the overall CO_2 emissions, helping achieve compliance with criterion 1 of AD L2A. This contribution is usually maximised by use of rooflight areas up to 20%. In many buildings the contribution of rooflights can be extremely significant – in the first example building, a building with no rooflights had overall CO_2 emissions over 35% higher than a building with 20% rooflight area.

Criterion 2: Limits on Design Flexibility (see AD L2A Paras 33-62)

Whilst achieving CO_2 emissions that comply with Criterion 1 allows considerable design flexibility, AD L2A also requires that reasonable provision should be made to limit heat gains and losses, and that energy efficient building services and controls be provided. The requirement on the building fabric would be met if the building complies with guidance in paragraphs 34-39, which cover insulation values of each element, and air permeability.

AD L2A Table 4 Limiting U-value standards ($W/m^2 \cdot K$) (extract)

Element	(a) Area-weighted average	(b) For any individual element
Wall	0.35	0.70
Floor	0.25	0.70
Roof	0.25	0.35
Windows, rooflights and curtain walling	2.2	3.3

Limiting U-values for rooflights

AD L2A Table 4 shows that the area-weighted average U-value of all the rooflights must not exceed $2.2W/m^2K$, whilst the U-value for any individual rooflight must not exceed $3.3W/m^2K$.

This means that where all the rooflights across a roof are the same, they must have a U-value of $2.2W/m^2K$ or better to achieve the average U-value requirement shown in column(a) of Table 4.

Note that if the rooflights differ on a single roof, it would be acceptable for some rooflights to have insulation values as poor as $3.3W/m^2K$ (as shown in column(b)), but the average (on an area weighted basis) must still be $2.2W/m^2K$. So if some rooflights were poorer insulated, others would have to be better, to keep the average constant. This flexibility is not relevant where all rooflights are the same.

Comments to AD L2A Table 4

- The requirement of 2.2 W/m^2K applies to the average insulation value of the entire rooflight after allowing for the effect of any glazing bars, kerbs or other thermal bridges
- This requirement will never be achieved by double skin plastic rooflights, but will usually be achieved by the use of triple skin rooflight assemblies
- Where a rooflight is constructed (in the factory or on site) using glazing bars, the effect of these glazing bars must be taken into account. Glazing bars that are truly thermally broken insulate better than the surrounding glazing material, and therefore have no detrimental effect on the insulating value of the rooflight. In other cases, the glazing bars may lead to some additional heat loss, which must be accounted for in the quoted U-value of the rooflight
- Out-of-plane rooflights are generally mounted on a kerb or upstand, which may or may not be as well or better insulated than the glazing material, and the thermal effects of this kerb must also be taken into account. Where kerbs are supplied with the rooflight, they should be regarded as part of the rooflight, and the effect of the kerb should be included in the U-value which is quoted for the rooflight. Where they are existing or manufactured on site, they can either be regarded as part of the rooflight, or as part of the roof (in which case they should meet the requirements for the roof)
- Appendix 3 gives further detail on how to allow for the effect of kerbs when assessing U-value

Buildings with high internal gains

There is a concession in para 38, which allows the average U-value for glazing to be relaxed from 2.2 to 2.7 W/m^2K in buildings with high internal gains, such as manufacturing process generating a lot of heat; this is only permissible if it can be shown that this reduces overall CO_2 emissions. This means that if (and only if) it can be shown that overall CO_2 emissions are reduced if rooflight U-value is increased from 2.2 to a maximum of 2.7 (with no other changes), for example by using SBEM, then the average insulation of the glazing can be reduced accordingly; the worst case value of $3.3W/m^2K$ still applies.

Summary of Criterion 2

In practice, where all the rooflights on a roof are the same, the rooflights must be at least triple skin or contain an insulating core, since double skin rooflights will never be able to achieve the U-value requirement of $2.2W/m^2K$ shown in column(a) of Table 4, nor the relaxed value of $2.7W/m^2K$ shown in para 38.

Criterion 3: Solar Overheating

Whilst correctly managed solar gain is a benefit, which can reduce heating requirements, it is a requirement of AD L2A that solar gain is limited, to avoid excessive internal temperature rise in summer. This would be achieved if the combined solar gain and other internal gains do not exceed 35 W/m².* The other primary internal gains in most buildings are typically occupants, artificial lighting and internal processes.

The other internal gains of a building define the maximum solar gain to ensure the sum total does not exceed 35 W/m². Research from De Montfort University has predicted the solar gain inside buildings for various rooflight areas, so the results can be used to equate the maximum allowable solar gain (which depends on other internal gains) to actual rooflight area. The results in the table below show the solar gains and associated rooflight areas for different levels of internal gain, which ensure the combined gains do not exceed 35 W/m², thus complying with the regulations and avoiding solar overheating.

Internal Gain (W/m²)	Maximum Solar Gain (W/m²)	Equivalent Rooflight (%)
0	35	21
5	30	18
10	25	15
15	20	12
20	15	10

Process heat gains

Any large plant or process facility may produce significant local heat gain (which can be in excess of the total limit of 35 W/m²). Where this is envisaged, localised heat extraction or cooling should be used to prevent overheating.

Internal gains due to artifical lighting

Internal gains due to lighting can be significant (for example, up to 15-20 W/m² in retail outlets), and could potentially present problems if artificial lighting was used in conjunction with rooflight areas over 10-12% at times of maximum solar gain.

However, the period of highest solar gain is simultaneous with the highest daylight illuminance; provided rooflight area is sufficient, the internal gains due to artificial lighting can be greatly reduced or eliminated by switching off the lights. Where this is done automatically (eg by photoelectric controls) the internal gain from artificial lighting would only be present when there is little daylight illuminance and hence little solar gain, so that it would seem reasonable to disregard the internal gain from artificial lighting when considering rooflight area.

AD L2A (para 63) states "specifying efficient lighting with effective controls will reduce internal gains that will also help to reduce internal temperature rise in summer when daylight availability is at a maximum".

Internal gains due to occupants

The final internal gain to consider is from occupants of the building, which depends highly on occupant density. Typically, in large industrial or storage facilities occupant densities are very low and the internal gain is almost insignificant and can be ignored, so rooflight areas up to 21% will not cause overheating. Practical experience in such buildings confirms this is reasonable.

Where occupant density reaches one person per 30m² (eg. large retail stores), internal gains may reach around 5 W/m² (since 1 person produces approx 140W seated or 160W light standing work or walking, rising to 265W when carrying out medium bench work), at this occupant density and level of internal gain, the table above shows rooflight areas up to 18% will not cause overheating.

Where occupant densities increase further (eg offices, classrooms etc), internal gains should be checked carefully against the table to determine the appropriate rooflight area.

In very densely occupied environments (e.g. call centres) internal gains due to occupants and equipment can be very high (up to 30 W/m²). This is approaching the total acceptable internal gain, which would be exceeded if all other gains are as low as 5 W/m², thus severely limiting the area of rooflight that is practical without use of mechanical cooling.

Direct radiant heat

It should also be noted that the quoted rooflight areas assume evenly distributed light from the rooflight. This depends on a degree of light diffusion from the rooflights, appropriate to the height between roof and ceiling, and the rooflight layout/distribution: the lower the ceiling, or less evenly spread the rooflights, the greater the level of diffusion required.

If rooflights are clear or do not provide sufficient diffusion then the direct radiant heat through the rooflights can produce localised overheating directly beneath the rooflights, regardless of rooflight area, in the same way as can occur adjacent to a window.

This can be resolved by using a rooflight layout which gives as even a spread of light as possible, in conjunction with an appropriate level of diffusion provided by the rooflight.

Summary of Criterion 3:

Rooflights generate some solar gain which is usually a benefit, reducing heating requirements and CO_2 emissions.

Rooflight areas up to 20% will not generally cause overheating, except where other internal gains are unusually high.

AD L2A (para 63) states: "When considering the proportion of glazing in a building, the designer should give consideration to the provision of adequate levels for daylight".

** see CIBSE TM37 "Design for Improved Solar Shading Control", 2006*

AD L2B Work on Existing Buildings that are not Dwellings

This NARM guidance document is designed to assist the user to understand the Guidance in AD L2B in respect of the use and application of rooflighting to repairs, refurbishment and extensions to existing buildings.

Definitions of Note

- Thermal Element is defined in Section 5 AD L2B Para 109. The Roof is a Thermal Element and does not include the rooflights
- Rooflights are Controlled Fittings and treated separately from Thermal Elements

Controlled Fittings

Rooflights are Controlled Fittings and where replacement, refurbishment or building extensions are required that involve rooflights, then they should be no worse than the U-values detailed in AD L2B Table 5– Standards for Controlled Fittings W/m²K

Comments to AD L2B Table 5

- The U-value requirement for "plastic" rooflights is 2.2W/m²K
- The requirement of 2.2 W/m²K applies to the average insulation value of the entire rooflight after allowing for the effect of any glazing bars, kerbs or other thermal bridges
- This requirement will never be achieved by double skin plastic rooflights, but will usually be achieved by the use of triple skin rooflight assemblies
- This requirement applies in all cases, including:
  - Rooflights in extensions
  - Replacement rooflights in existing roofs
  - New rooflights in refurbished roofs
- "Plastic" rooflights refers to all rooflights, except those glazed with glass. These will generally be Glass Reinforced Polyester (GRP) or Polycarbonate. Alternative plastics may be available but are not generally specified in the UK market, as they do not usually meet non-fragility and/or fire performance requirements
- Where a rooflight is constructed (in the factory or on site) using glazing bars, the effect of these glazing bars must be taken into account. Glazing bars that are truly thermally broken insulate better than the surrounding glazing material, and therefore have no detrimental effect on the insulating value of the rooflight. In other cases, the glazing bars may lead to some additional heat loss, which must be accounted for in the quoted U-value of the rooflight
- Out-of-plane rooflights are generally mounted on a kerb or upstand, which may or may not be as well or better insulated than the glazing material, and the thermal effects of this kerb must also be taken into account. Where kerbs are supplied with the rooflight, they should be regarded as part of the rooflight, and the effect of the kerb should be included in the U-value which is quoted for the rooflight. Where they are existing or manufactured on site, they can either be regarded as part of the rooflight, or as part of the roof (in which case they should meet the requirements for the roof)
- Appendix 3 shows how the area weighted average U value is calculated to allow for the effects of the kerb, this method is also appropriate here.

Buildings with high internal gains

There is a concession in para 77, which allows the average U-value for glazing to be relaxed from 2.2 to 2.7 W/m²K in buildings with high internal gains, such as manufacturing process generating a lot of heat; this is only permissible if it can be shown that this reduces overall CO_2 emissions. This means that if (and only if) it can be shown that overall CO_2 emissions are reduced if rooflight U-value is increased from 2.2 to a maximum of 2.7 (with no other changes), for example by using SBEM, then the average insulation of the glazing can be reduced accordingly; the worst case value of 3.3W/m²K still applies.

AD L2B Table 5 Standards for controlled fittings (W/m²·K) (extract AD L2B 2006)

Fitting	(a) Standard for new fittings in extensions	(b) Standard for replacement fittings in an existing building
Windows, roof windows and glazed rooflights	1.8 for the whole unit OR 1.2 centre pane	2.2 for the whole unit OR 1.2 centre pane
Alternative option for windows in buildings that are essentially domestic in character, a window energy rating of	Band D	Band E
Plastic rooflights*	2.2	2.2

**This is an extract from the correct table. The AD published in April 2006 omits this line in error. This will be included in future revisions of AD L2B*

Extensions under AD L2B

- Large extensions that are greater than 100m^2 and (note not "or") greater than 25% of the floor area of the existing building are to be regarded as new buildings and guidance AD L2A will apply
- Conservatories less than 30m^2 are exempt from Building Regs and do not apply to this Guidance
- For existing buildings that exceed 1000m^2 floor area, an extension will trigger Consequential Improvements to the original building. Comment on Consequential Improvement follow later in this document; see page 12
- Applies to enclosing existing structures such as covering over a courtyard

Rooflight design for Building Extensions

Extensions that fall under the requirements of AD L2B will be compliant if built to the Elemental Method and subject to given design constraints. In respect of rooflights, reasonable provision will be if:
(1) the rooflight U-values are 2.2 W/m^{2}K or better as shown in AD L2B Table 5 (page 10) and paras 26 and 75
(2) areas are limited as detailed in AD L2B Table 2 (below) and para 27

It is to be noted that for all extension types, the rooflight area is limited to 20% of the floor area. However, also note in Para 27, that where the existing building has in excess of 20% rooflight area, a reasonable provision for the extension will be to have a rooflight area which is limited to the same % of roof area as the original building to which the extension is attached.

Extensions with Optional Approach with more design flexibility

Paragraph 29 of AD L2B allows for more design flexibility by varying U-values, on a constant area weighted U-value basis, if opening areas vary from those shown in AD L2B Table 2 (below).

However, the average U-value for each element may not be any worse than shown in column (a) of AD L2B Table 3 (below). This means the average U-value of all the rooflights on a building must still be 2.2W/m^{2}K or better, so no reduction in rooflight insulation value is permitted if rooflight area is reduced (thus removing the "trade-off" in rooflight U-values which was permitted under 2002 regulations).

Column (b) of AD L2B Table 3 shows that an individual rooflight(s) may be permitted to have poorer insulation value (max U-value 3.3 W/m^{2}K). However, the area weighted average must still achieve 2.2W/m^{2}K, so if some rooflights are poorer insulated, others must achieve higher performance to achieve the necessary average. This is only likely to apply if, for example, there are different types of rooflights within a roof where some may not be able to achieve a U-value of 2.2W/m^{2}K.

AD L2B Table 2 Opening areas in the extension (extract)

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
Smoke vents	N/A	As required

AD L2B Table 3 Limiting U-value standards (W/m^{2}K)

Element	a. Area weighted average U-value	b. Limiting U-value
Wall	0.35	0.70
Floor	0.25	0.70
Roof	0.25	0.35
Windows, roof windows, rooflights and doors	2.2	3.3

Reducing rooflight area will increase energy use of artificial lighting systems; the research from De Montfort University and results from SBEM show that reduction in rooflight area will generally increase consumption of energy, and emissions of CO_2, as well as losing the widely recognised benefits of a naturally lit interior, and will thus increase the carbon footprint of the extension.

This point is emphasised in **AD L2B para 29** which states **"In industrial buildings, rooflights are a beneficial source of daylight, and so significant reductions in rooflight area could result in increased use of electric lighting".**

Great care should therefore be exercised if rooflight area is reduced significantly from the 20% area shown in AD L2B Table 2, in this type of building.

Work on Controlled Fittings – Replacement and Refurbishment

AD L2B (para 75) covers requirements where-ever a controlled fitting is being replaced. If rooflights need replacing, for what ever reason, then compliance will be achieved by following Column (b) in AD L2B Table 5 shown above.

There is **no** requirement that where one or a number of rooflights are to be replaced, then all the rooflights should be replaced. The only requirement is that those that are replaced, meet the new standards as set out above.

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 initial provision or capacity increase of any fixed building services, then a requirement for "consequential improvement" to the building to improve the energy performance of the original building is triggered, to a value of 10% of the main project works.

Consequential improvement is only required if both technically and economically feasible, the latter defined by a simple payback of 15 years.

The Guidance Document provides a list of 8 practical solutions to upgrade the original building that is shown in **AD L2B Table 1 – Improvements that in ordinary circumstances are practical and economically feasible. Item 7** identifies **"Replacing existing windows, roof windows or rooflights or doors which have a U-value worse than 3.3 W/m^2K".** This is saying that an acceptable step to compliance to achieve consequential improvement is to replace old rooflights that have U-values greater than 3.3 with new rooflights that have U-value of 2.2 W/m^2K

Since there will be a basic requirement to upgrade the original building in line with the financial limits stated, there will be considerable advantage to selecting **Item 7** as one of the improvements costs since –

- There will be considerable thermal efficiency savings by replacing old rooflights at a U-value of 5.7 W/m^2K to new rooflights at a value of 2.2W/m^2K
- 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
- The new rooflights may be specified to be non-fragile making the roof a safer place should maintenance staff need to access the roof.

Frequently asked Questions on Rooflight Refurbishment

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

   A repair does not constitute a material alteration and does not come under the control of these Regulations. A replacement rooflight comes under work on Controlled Fittings (AD L2B para 75) and reasonable provision will be to fix replacement rooflights to a U-value of 2.2W/m²K in compliance with ADL2B Table 5 column (b). (1)(2)

2. **I want to replace all the old rooflights.**

   All replacement rooflights in an existing building should achieve a U-value of 2.2 W/m²K or better, as shown in AD L2B para 75 and Table 5 column (b). This U-value requirement means that replacement rooflights have to be triple skin: double skin plastic rooflights will not achieve a U-value of 2.2 W/m²K. (1)(2)

3. **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. Thus rooflights may be added to achieve a 20% area. All such additional rooflights should have a U-value of 2.2 W/m²K. (2)Where the existing rooflights are retained, without any work carried out on them, there is no requirement to upgrade their thermal performance.

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 2.2 W/m²K. 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. Additionally the extension may trigger a "Consequential Improvement" on the original building. As detailed above in the previous section of this document, one way to provide Consequential Improvement will be to upgrade the rooflights of the original building.

5. **I want to over-roof my building which has rooflights within it. Does the over-roof fall under the Part L Regulations?**

   Over-roofing is defined as Renovation being the addition of an extra layer to a Thermal Element. Renovation to a Thermal Element is described in AD L2B paras 85 and 86. Where practical the renovated roof should achieve a standard that is set out in AD L2B Table 7 column (b) (not reproduced in this document) with U-values for the Thermal Element at 0.25 W/m²K.
   AD L2B para 85 also advises that where the work is less than 25% of the surface area of the roof, a reasonable provision could be to do nothing to improve the energy performance.
   Even for a complete over-roof, it may not be technically or functionally feasible, or may not achieve a simple payback of 15 years or less, in which case the element should be upgraded to the best standard to suit this criteria - see AD L2B para 88
   Where rooflights are included in an over-roof, where possible the rooflights should have a U-value of 2.2 W/m²K(2). This U-value requirement means that replacement rooflights have to be triple skin (which may include the original rooflight skin(s), if retained): double skin plastic rooflights will not achieve a U-value of 2.2 W/m²K.

6. **I only want to replace the outer sheet of the rooflight.**

   Replacement of the outer sheet constitutes renovation of a controlled fitting, which is not covered specifically in AD L2B. However, AD L2B (para 85) covers renovation of thermal elements, and states that a renovated element should meet an improved standard (shown in Table 7 column (b)) which is the same performance level as that for replacement thermal elements (shown in Table 6 column (B)). On similar basis, renovated rooflights should achieve the performance level for replacement rooflights as shown in AD L2B Table 5 column (b) (see page 10 of this document) ie. 2.2W/m²K(2) which requires the use of triple skin rooflights.

7. **I only want to replace a small proportion of the rooflights.**

   The performance level for replacement rooflights is shown in AD L2B Table 5 column (b) (see page 10 of this document) regardless of however small or large a proportion of the rooflights are being replaced. This requires a performance of 2.2W/m²K(2) which requires the use of triple skin rooflights.

8. **I only want to replace the outer sheet on a small proportion of the rooflight.**

   Replacement of the outer sheet constitutes renovation of a controlled fitting, which is not covered specifically in AD L2B. However, AD L2B (para 85) covers renovation of thermal elements, and states that where work applies to less than 25% of the area of a particular element, reasonable provision could be to do nothing to improve the energy performance. On similar basis, it could be argued that it is reasonable to do nothing to improve the thermal performance of a rooflight where less than 25% of that rooflight is being renovated (ie replace like for like). Where the outer sheet of more than 25% of any individual rooflight is being replaced refer to question 6 above.

(1) Where the kerb/upstand of an out-of-plane rooflight is also replaced, then the kerb should be treated as part of the rooflight, and the area weighted average U-value of the rooflight and kerb (see Appendix 3, page 22) should achieve 2.2 W/m²K

(2). The limiting U-value of 2.2 W/m²K should apply to all rooflights, after taking into account the effect of glazing bars and kerbs – as detailed in comments to AD L2B Table 5, page 10

Appendix 1
The De Montfort University Research

Assessing the overall impact of rooflights and glazing on the energy efficiency of a building is a complex task. Consideration was given to the glazing's inferior insulation 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 rooflight.

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 rooflight area on both 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 analysed the heat flow and illuminance through an entire roof for rooflights covering between 0 and 20% of the roof area.

Thermal analysis used 'EnergyPlus' software, widely recognised as accurate for this type of work, which 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.

Illumination levels inside a building for different rooflight areas and types were also calculated. The design illumination level, and efficiency of the lighting and control systems define the energy needed to provide artificial lighting. The results show the effect of rooflight area on annual lighting system energy use on an hour-by-hour basis throughout the year 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 then 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 illumination level, type of artificial lighting control used and the pattern 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.

Figure A1.1: Effect of rooflight area on CO_2 emissions due to artificial lighting system

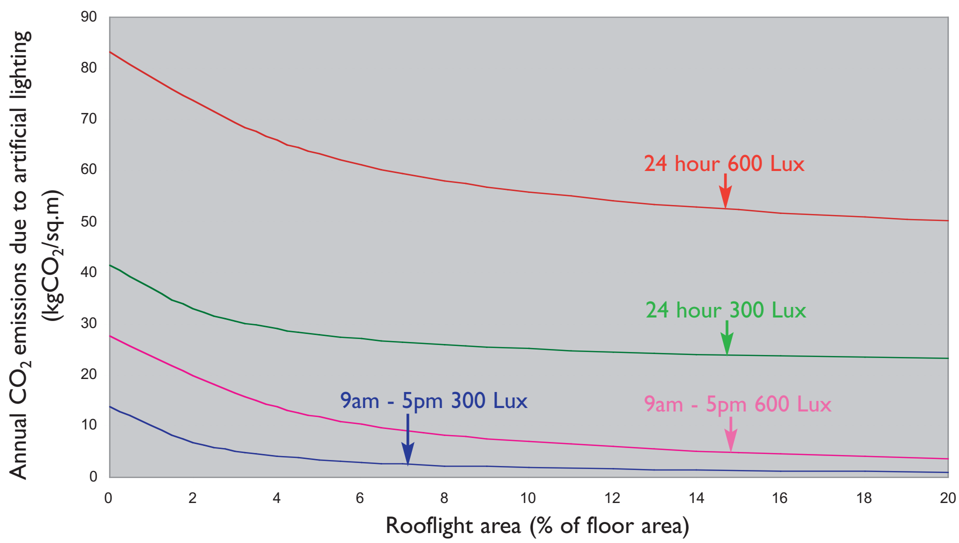


Figure A1.2: Effect of rooflight area on total CO_2 emissions 9am-5pm

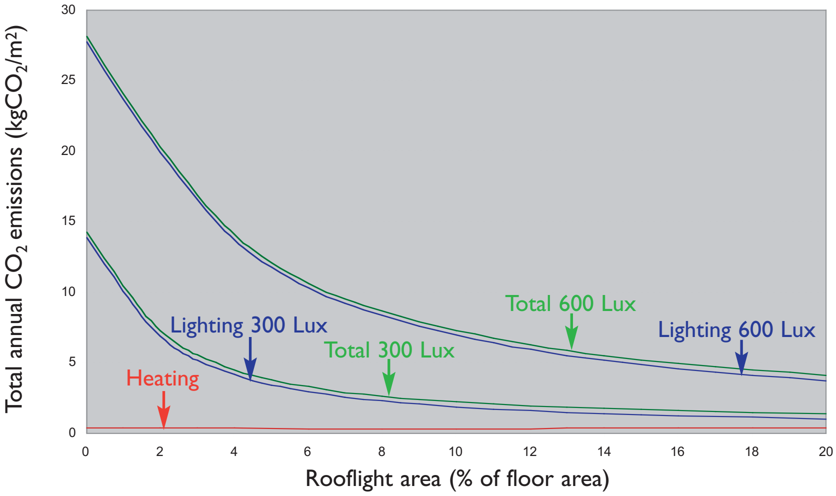
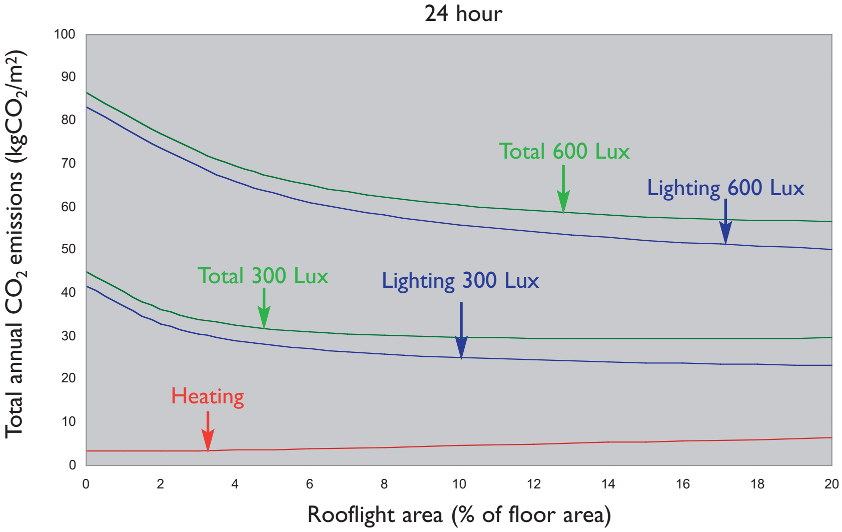


Figure A1.3: Effect of rooflight area on total CO_2 emissions 24 hour



For example, with 300 lux illumination and 9am-5pm use, there is a reduction in lighting system's CO_2 emissions from 14 to1 $kgCO_2/m^2$ 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. Increasing rooflight area will be a straightforward way of helping to meet a building's target emission levels under the new Building Regulations.

Figure A1.2 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, 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 green 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 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.

A building with 20% rooflights occupied 9am-5pm for 365 days a year with a lighting requirement of 300 lux (including 20%) will save 23 kg CO_2/m^2 or a massive 85% saving in

CO_2 emissions compared to the same building without rooflights.

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 A1.3 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:
  - the savings are significant as rooflight area increases up to 15% in all cases
  - where illumination levels are relatively low, the further savings as rooflight area is increased above 15% are relatively minor
  - there are significant further savings as rooflight area increases up to 20% at higher illumination levels
- in buildings used 24 hours a day:
  - there are savings as rooflight area increases up to 15% in all cases
  - 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%
  - 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.

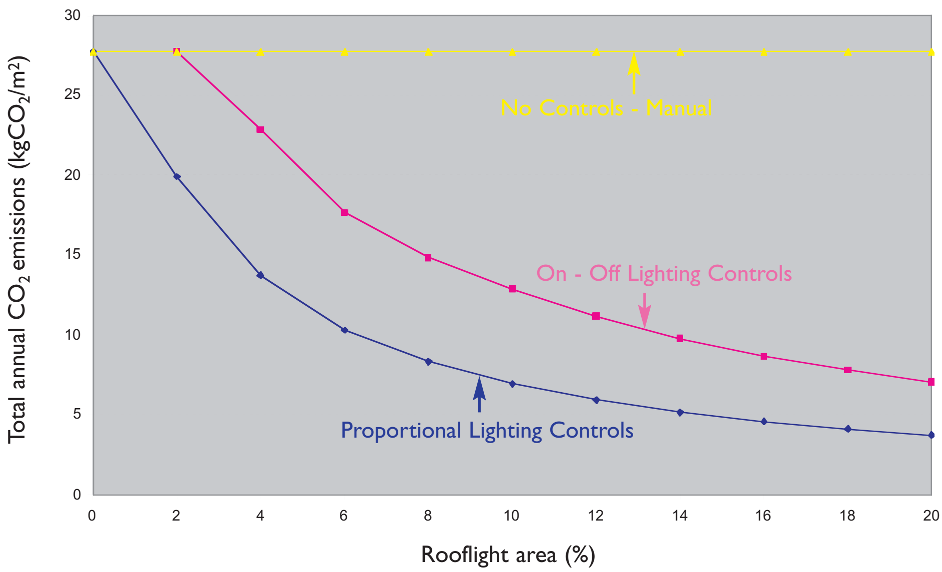
Appendix 2
Artificial Lighting Control

The DMU work also highlighted the importance of appropriate lighting controls to maximise the benefits of natural daylight via rooflights. Simple on/off photo-electric cells that switch off lighting systems whenever daylight levels are higher than the design illumination levels will save considerably on energy usage. This can be further improved by proportional control systems which reduce power to lighting systems, using them as 'top-up' to the desired illumination level, whenever there is any background daylight available. The worst case scenario is where the lack of automated control could mean lights are left on even when an excess of natural light is available - wasting all the energy to the lighting system, which is converted to heat within a building and increases risk of overheating, creating the worst possible carbon footprint. Note that the 'manual control' option within SBEM assumes some control, rather than this worst case scenario.

The following graphs show the effect on energy usage by the type of lighting control that is employed.

The SBEM computer model accommodates different levels of lighting control to ensure that full advantage is taken to save on the considerable carbon cost of leaving the lights on when not required.

Figure A2.1: Effect of lighting system controls (for 500 Lux 9am - 5pm)



Appendix 3

How to enter rooflight data into iSBEM

(a) generic rooflight data

The type(s) of rooflight which are going to be used on any particular building are entered into SBEM in the "Project database" tab, under the "Glazing" subtab.

They can be imported from the library; Figure A3.1 shows this data entry screen, together with the options in the library.

As shown in figure A3.1, the library includes entries for:

- in-plane rooflights
- dome/pyramid rooflights
- barrel vault rooflights
- panel glazing systems
- architectural skylights

and for each of these rooflight types, includes options for single, double, triple variants.

Note that single and double skin options should only be used where existing buildings are being analysed: for new build, or extensions, all rooflights should be triple skin or better to achieve a U-value of 2.2 W/m²K as shown in AD L2A Table 4 (see section on AD L2A, criterion 2, on page9).

In addition the user has to enter frame type, which will modify the U-values appropriately. Note that some rooflights (eg in-plane rooflights) have no frame: there is a "no frame" option which should be entered accordingly. There are also options for other frame systems (eg metal frames), although the default values are slightly pessimistic, and where full details of the thermal performance are know, it may be advantageous for the user to enter an overall U-value which accounts for the effects of the frame (see below).

Figure A3.1

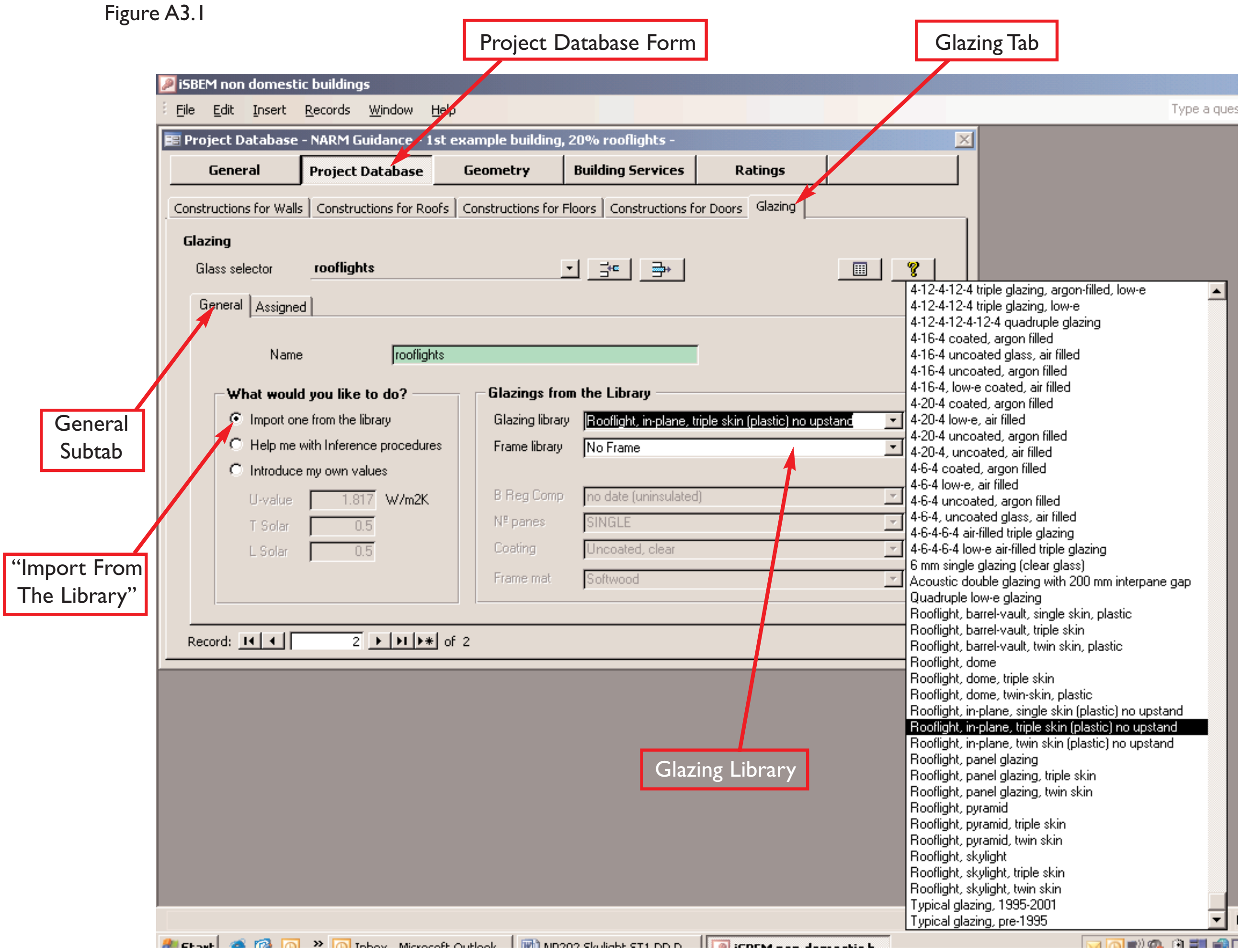
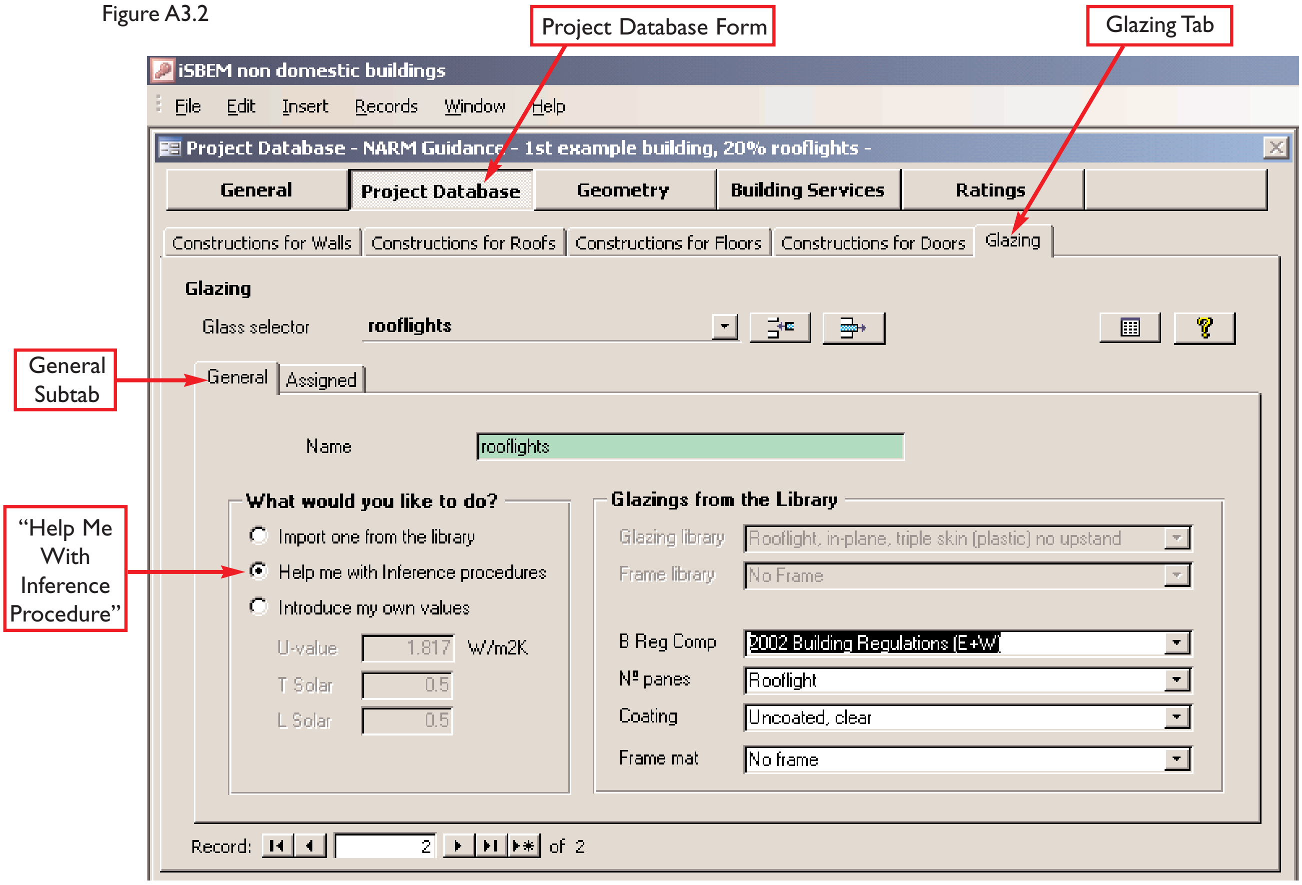


Figure A3.2



Alternatively, if the detail of the rooflight is unknown, "inference procedures" can be used to determine the likely rooflight properties from the age of the building. Fig A3.2 shows the data entry screen for this option. This method will generally give poorer rooflight properties than if additional details are known.

Introduction of user values

SBEM also gives an alternative option to enter properties for the rooflight directly; these are the U-value, L-solar, and T-solar values. Fig A3.3 shows the data entry screen for this method.

U-value

When entering a U-value, the effect of any glazing bars must be taken into account (wherever a rooflight is constructed, either in the factory or on site, using glazing bars).

Some glazing bars are truly thermally broken, so insulate better than the surrounding glazing material, and therefore have no detrimental effect on the insulating value of the rooflight – in such cases the U-value of the "centre pane" glazing material can be entered.

In other cases, the glazing bars may lead to some additional heat loss, which must be accounted for in the U-value of the rooflight which is entered into SBEM.

Out-of-plane rooflights are generally mounted on a kerb or upstand, which may or may not be as well or better insulated than the glazing material, and the thermal effects of this kerb must also be taken into account.

Where kerbs are supplied with the rooflight, they should be regarded as part of the rooflight, and the effect of the kerb must be included in the U-value entered for the rooflight. Where kerbs are existing or manufactured on site, they can either be regarded as part of the rooflight, or as part of the roof (in which case they should meet the requirements for the roof).

The requirements (2.2 W/m²K average, or 3.3 W/m²K for any individual element, as shown in AD L2A Table 4 and AD L2B Table5) apply to the average insulation value of the entire rooflight after allowing for the effect of any glazing bars, kerbs or other thermal bridges.

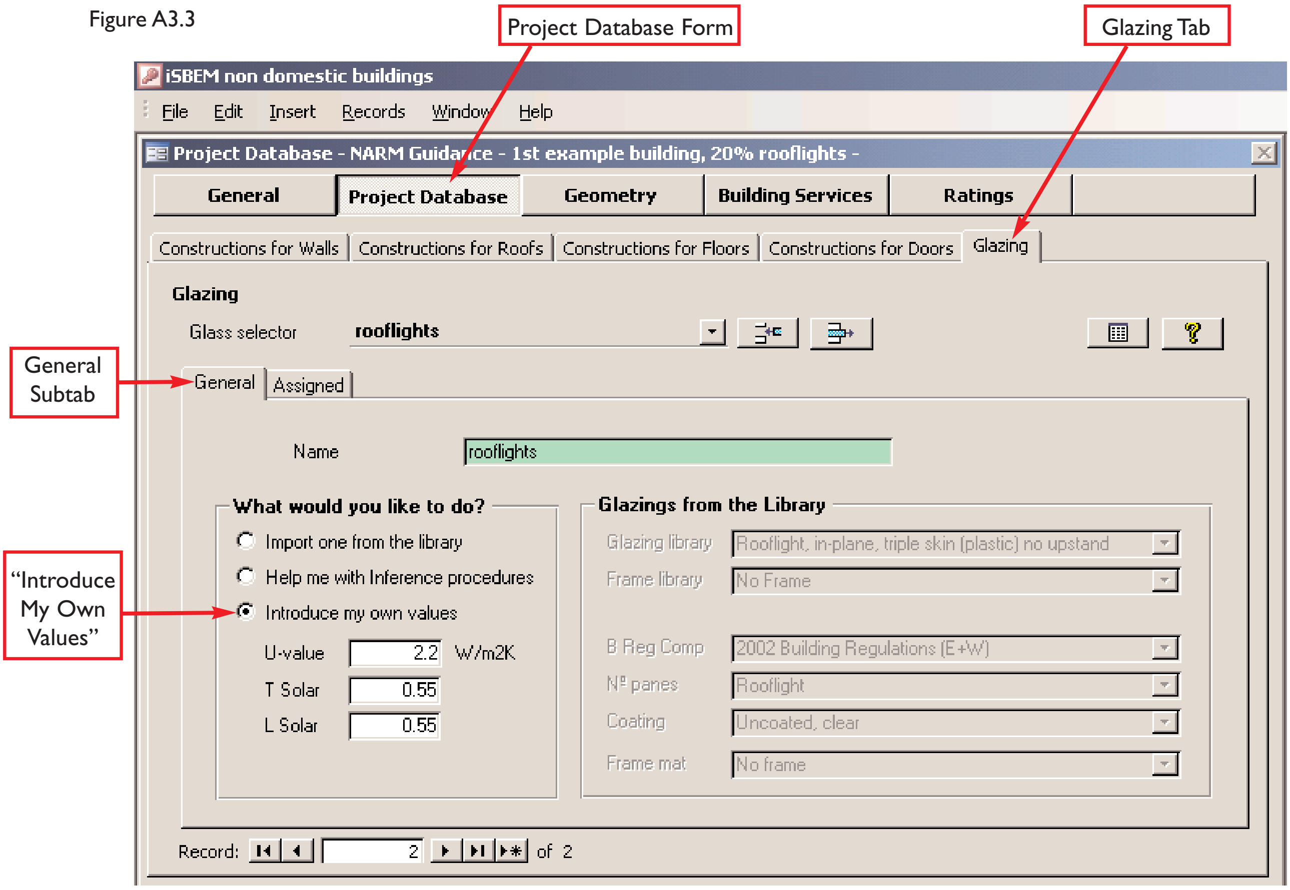
L-solar

L-solar is the light transmission, and the value from the database should be modified with the correct value for the product being used, where verified data is available.

T-solar

T-solar is the total solar transmittance, which for plastic materials is usually very close to the L-solar value, and in the absence of any verified data the same value should be entered.

Figure A3.3



Project Database Form
Glazing Tab
General Subtab
"Introduce My Own Values"
iSBEM non domestic buildings
File Edit Insert Records Window Help
Project Database - NARM Guidance - 1st example building, 20% rooflights -
General
Project Database
Geometry
Building Services
Ratings
Constructions for Walls
Constructions for Roofs
Constructions for Floors
Constructions for Doors
Glazing
Glazing
Glass selector
rooflights
General
Assigned
Name
rooflights
What would you like to do?
Import one from the library
Help me with Inference procedures
Introduce my own values
U-value
2.2
W/m2K
T Solar
0.55
L Solar
0.55
Glazings from the Library
Glazing library
Rooflight, in-plane, triple skin (plastic) no upstand
Frame library
No Frame
B Reg Comp
2002 Building Regulations (E+W)
Nº panes
Rooflight
Coating
Uncoated, clear
Frame mat
No frame
Record:
2
of 2

(a) Rooflight geometry

Once all the types of construction have been entered under the "Project Database" tab (including rooflights under the "Glazing" subtab), the geometry of the building is entered under the "Geometry" tab.

Rooflights are entered under the "Windows & Rooflights" subtab as shown in figure A3.4

Rooflights can either be entered directly from this screen (and assigned to a particular element of the envelope, which should always be a roof), or can be can be entered directly from the quick envelopes subtab for each zone as the various elements are being created, as shown in Figure A3.5

Figure A3.4

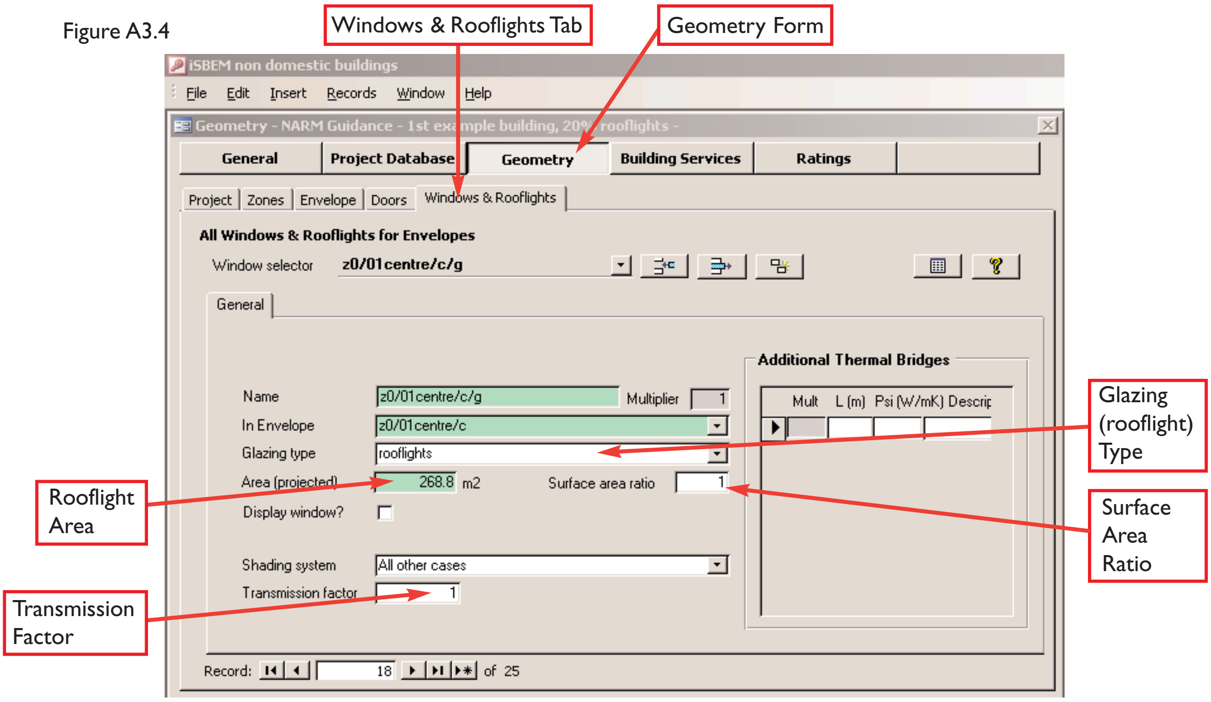
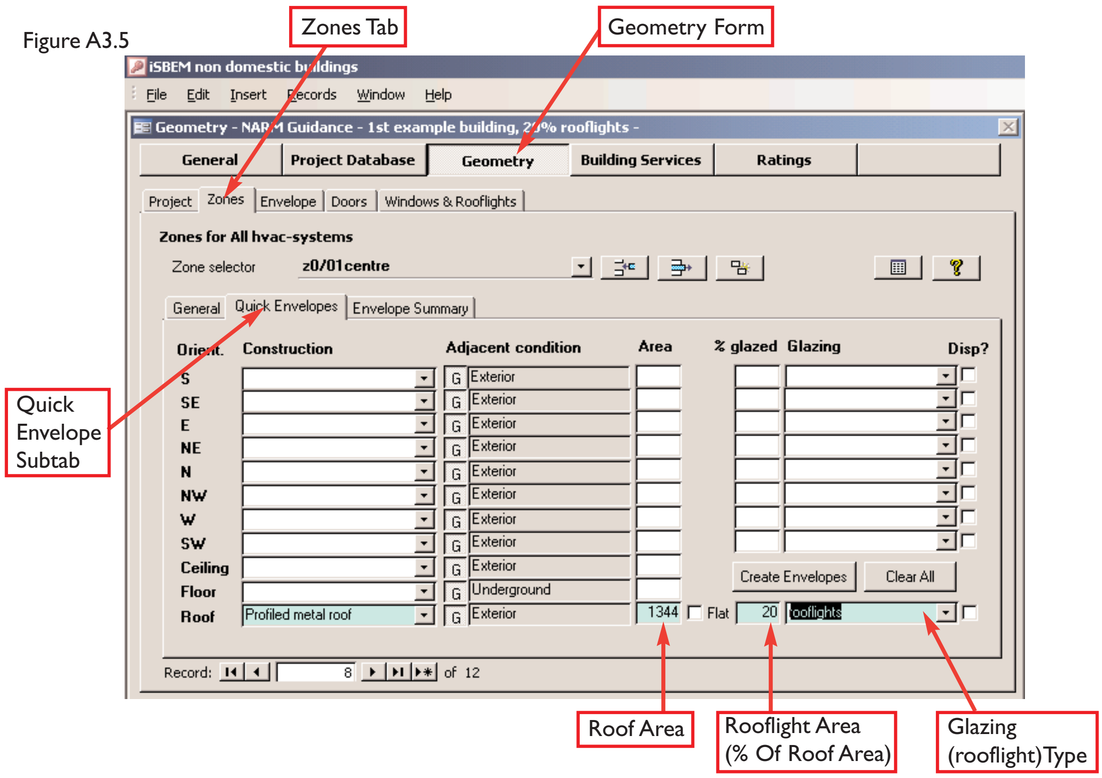


Figure A3.5



Whichever way the rooflight is initially entered, the area is entered (either as square metres as shown in Figure A3.4, or % of the roof area for the particular zone as shown in Figure A3.5), but surface area ratio and transmission factor must always be corrected as shown in Figure A3.4.

Surface area ratio

This is the ratio of the total surface area of the rooflight compared to the area of the opening (the daylight area). Where the element into which glazing is being entered in a wall, SBEM assumes the glazing is a window and sets this value to 1.0, but where the element is a roof, SBEM assumes the glazing is a rooflight and sets the default to 1.3

However, the actual surface area ratio will vary from one type of rooflight to another; if detail values for a particular rooflight are not available, the following default values should be entered for the rooflight itself (overwriting the value of 1.3 assumed by SBEM)

- in-plane rooflights 1.0*
- dome rooflights 1.25
- pyramid rooflights 1.4
- low rise barrel vault rooflights 1.1
- panel glazing systems 1.0
- architectural skylights 1.4

*The U-value quoted for profiled in-plane rooflights should account for the effect of the profile – or, alternatively, a U-value for flat sheet can be used, but then the surface area ratio should be adjusted to account for the effect of the profile.

In addition, for any out of plane rooflight, the area of the kerbs should be taken into account in this factor. For long runs of barrel vault rooflights on low kerbs this is likely to be insignificant, but for small domes on tall kerbs this may be quite high.

Figure A.3.6 shows a schematic diagram of an out-of-plane rooflight.

If: R = surface area of the rooflight
K = surface area of the kerb
D = the minimum daylight area

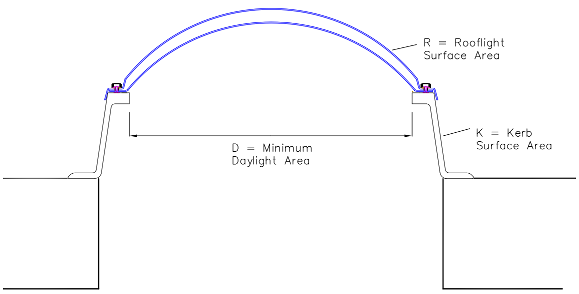
The surface area ratio of the rooflight itself is then defined by the formula $\frac{R}{D}$

Typical values for this ratio for different types of rooflight are as shown above.

Kerbs / upstands can be treated in one of 3 ways:

- Regard the kerb as part of the roof, in which case the upstand should be insulated to the same standard as the rest of the roof - which is unlikely in practice
- Regard the kerb as a detail on the roof, which is not as well insulated as the rest of the roof, and therefore has an associated psi value which must be entered into SBEM. In theory this is a valid approach, but entry of the correct data into SBEM is difficult.
- Regard the kerb as part of the rooflight – this is the most practical approach.

Figure A3.6 Schematic of out-of-plane rooflight



If the kerb is treated as part of the rooflight, the U-value entered for the rooflight should be the area weighted average of the U-value of the rooflight and the kerb

If: U_R = U-value of the rooflight (after allowing for the effect of any frame and glazing bars)
U_K = U-value of the kerb,

then the area weighted average U-value to be entered into SBEM is defined as:

$$\frac{(R \times U_R) + (K \times U_K).}{(R + K)}$$

This value should still comply with the worst case U-value requirement (typically 2.2 W/m^2K).

In addition, the surface area ratio should be adjusted to account for the area of the kerb, and should be defined by the formula $\frac{R + K}{D}$

Shading system

There is generally no shading system (eg blinds etc) on rooflights, and this should therefore be set to "All other cases".

Transmission factor

This factor reflects the loss of transmission due to shading eg from overhangs above a window, and the default is set to 0.8. However, since there is generally no shading on a rooflight, the default value for glazing (including windows) should normally be overwritten with a value of 1.0 for rooflights.

Lighting and lighting control systems

Details of the lighting system are entered under the "Building Services" tab, and the "zones" subtab, under the heading "lighting (general)". There are 3 options:

- the type of lighting systems can be entered from a library (as shown in figure A3.7)
- the load of the lighting circuit can be specified for some building types (as shown in figure A3.8); for some building types this option is not available. Note that Part L2 2002 stated that lighting systems should be reasonably efficient, and that a way of achieving this would be to provide lighting of 40 luminaire-lumens per circuit watt. This would therefore be a reasonable value to enter for a building built to 2002 standards, whilst AD L2B (para 56) states that reasonable provision would be lighting of 45 luminaire-lumens per circuit watt
- if a full lighting design has been carried out, the total circuit wattage and design illuminance can be entered (as shown in figure A3.9) Note that the "design illuminance" figure is the illuminance which the lighting system has been designed to achieve; SBEM uses this figure solely to establish the efficiency of the lighting system. It is **not** the design illuminance level for the zone, which is fixed in the SBEM database. Entering a higher value here therefore does not imply a brighter internal environment, it just defines a more efficient lighting system.

Figure A3.7

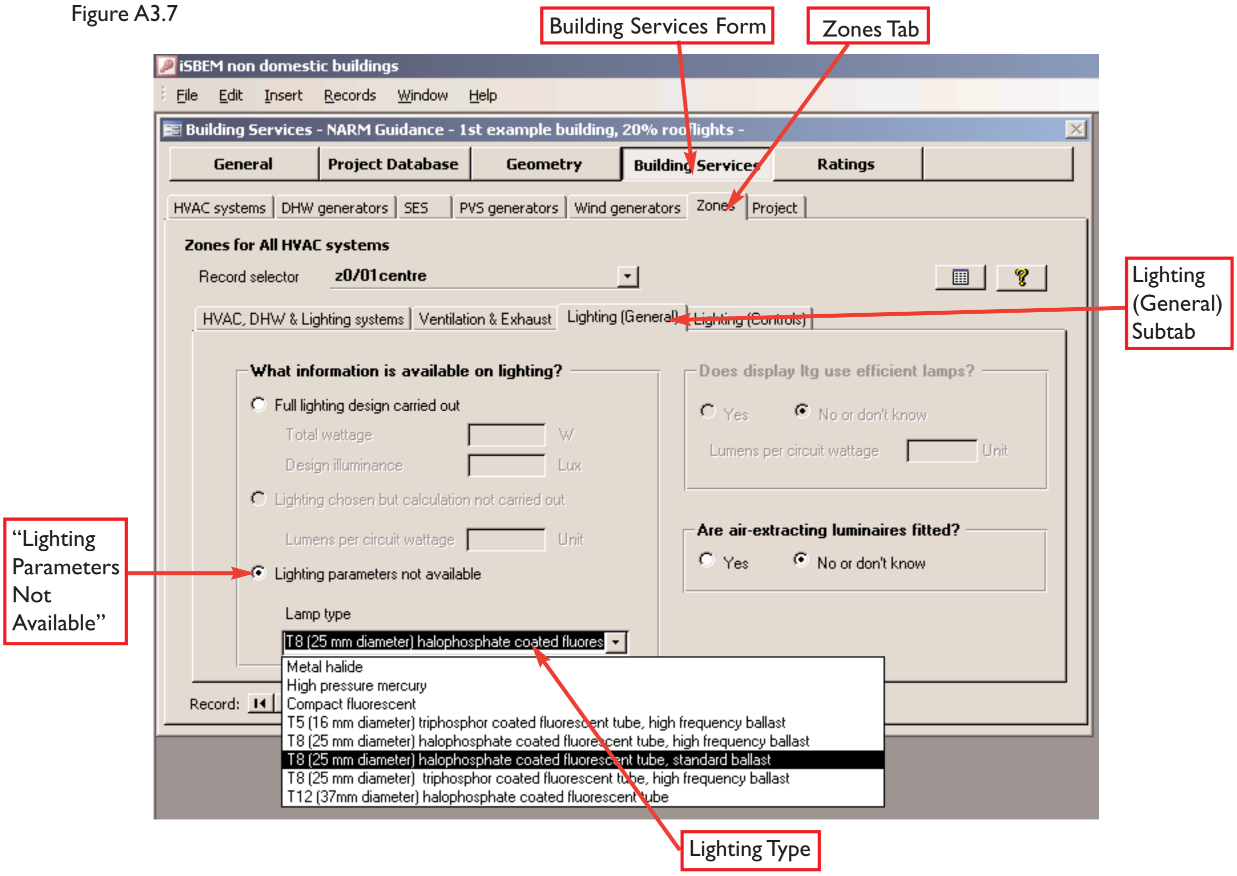
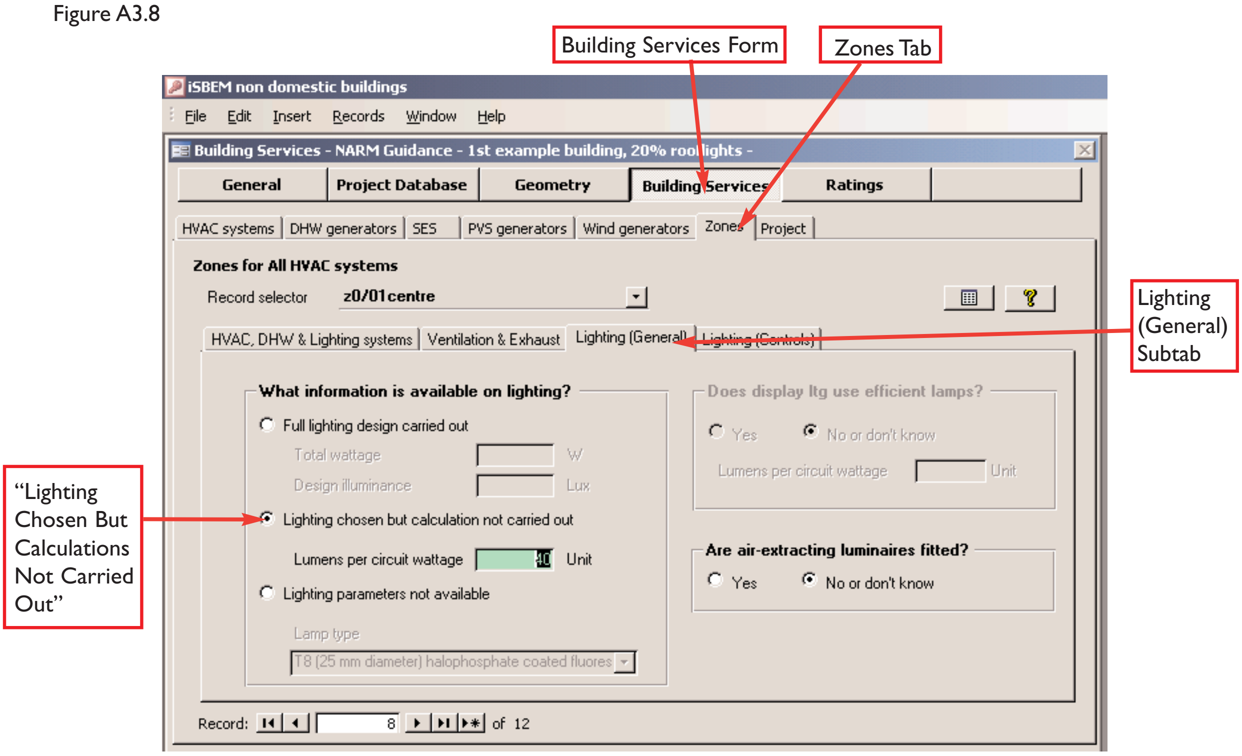


Figure A3.8



The lighting control system details are entered under the "Building Services" tab, and the "zones" subtab, under the heading "lighting (controls)" as shown in Figure A3.10 The user can select either local manual switching, or photoelectric, or both; each of these options can reduce the energy consumption of the lighting system. When photoelectric controls are selected, the user can also select switching (on-off) or dimming (proportional) and can also set the parasitic power of the control system i.e. the energy per square metre that the lighting system continues to use even when the lights are turned off. Note that the higher this value is, the less the energy saving achieved by turning off the artificial lights since the system continues to consume energy, so the saving offered by the use of rooflights will be reduced and the overall CO_2 emissions will be increased.

The user can also add metering provision for lighting control systems under the "project" subtab which can reduce the energy consumption of the lighting system.

Figure A3.9

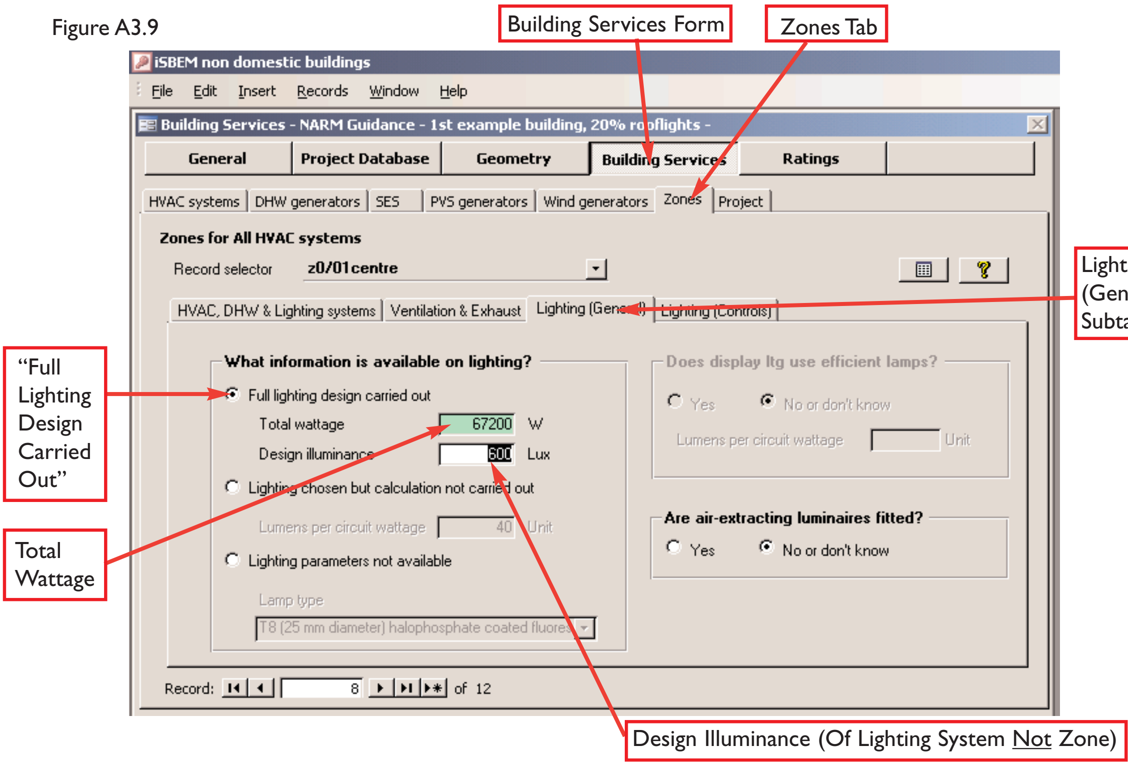
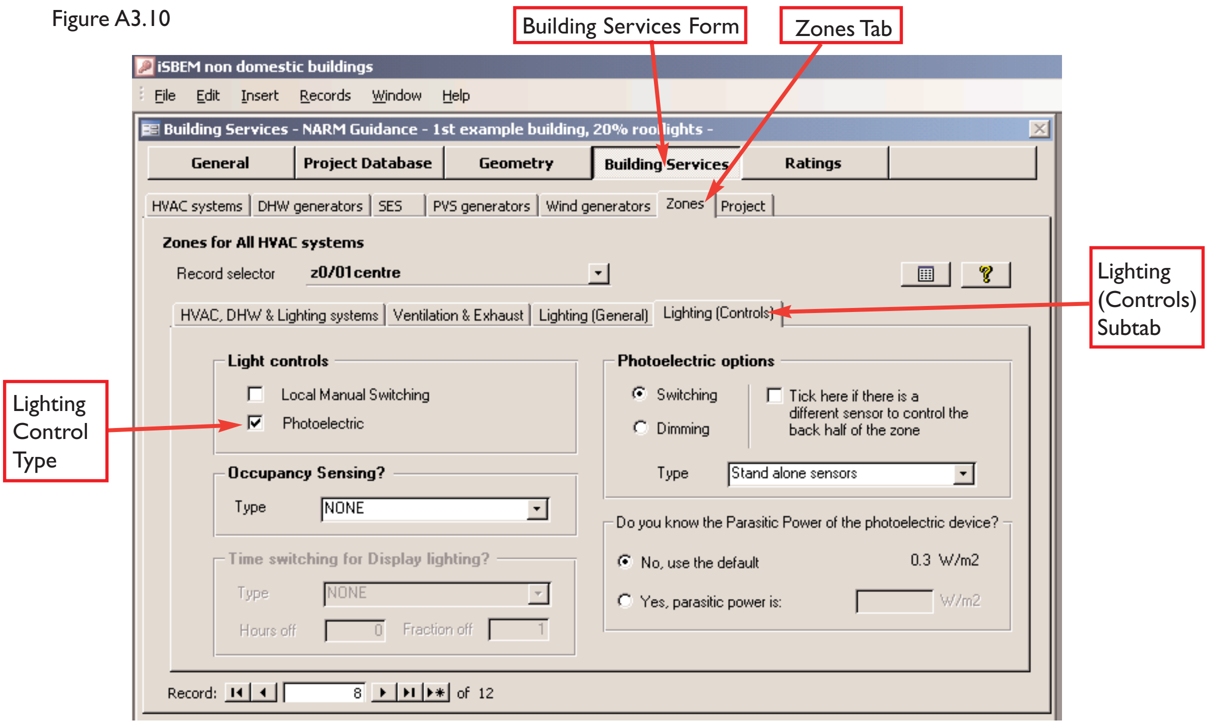
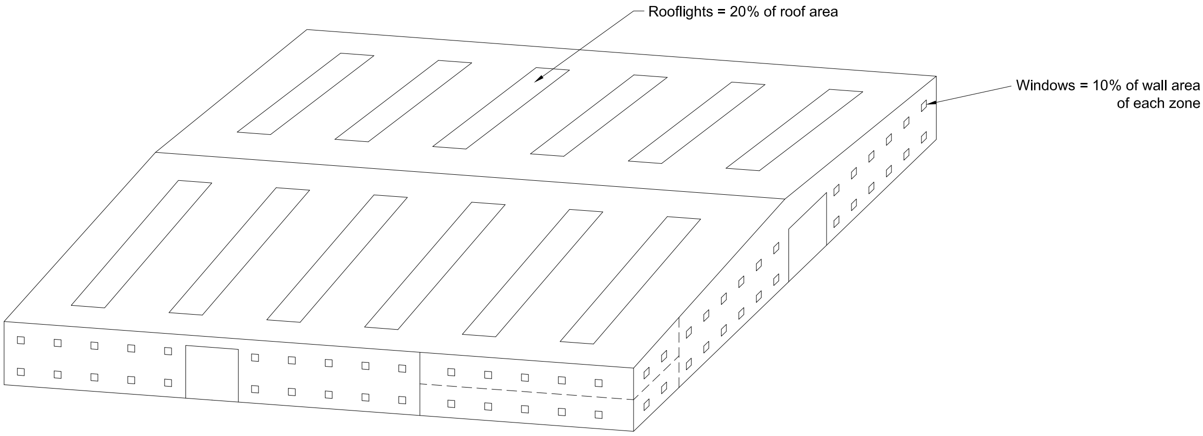


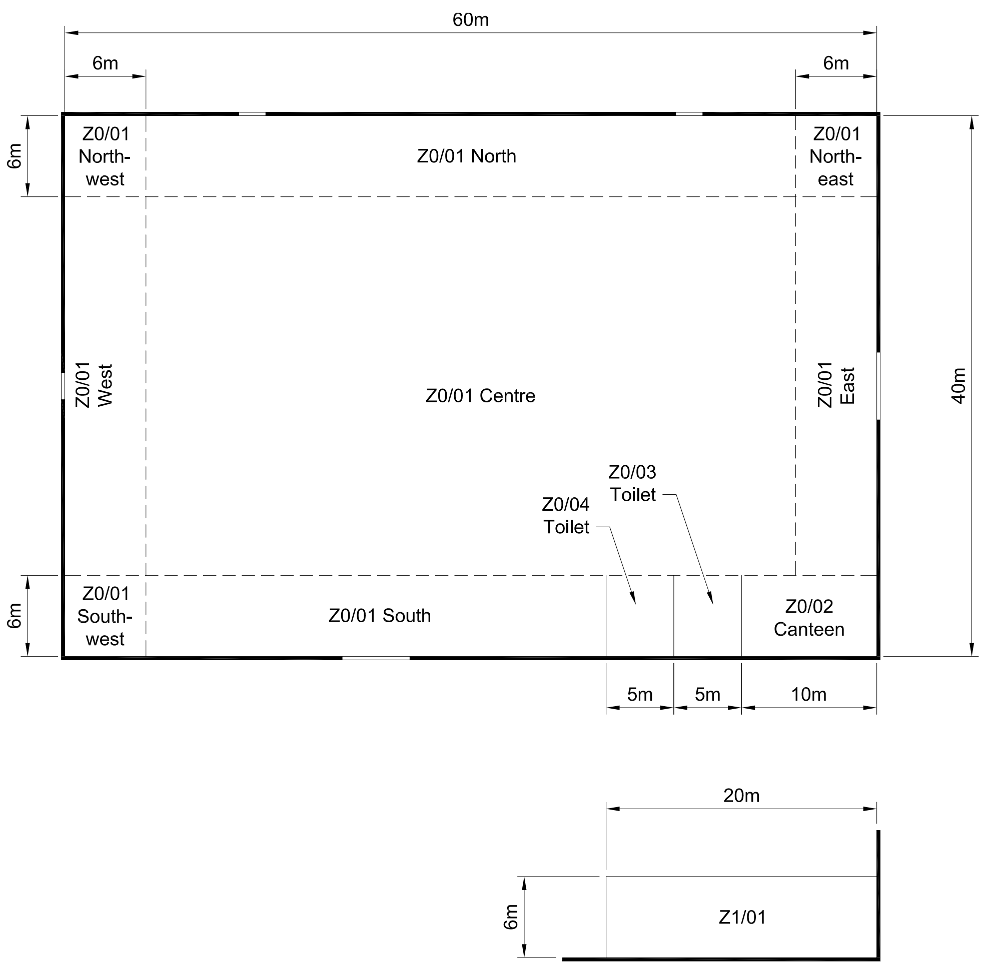
Figure A3.10



Appendix 4
Detail of example buildings analysed by SBEM

Example 1: Large Open Span Metal Clad Building

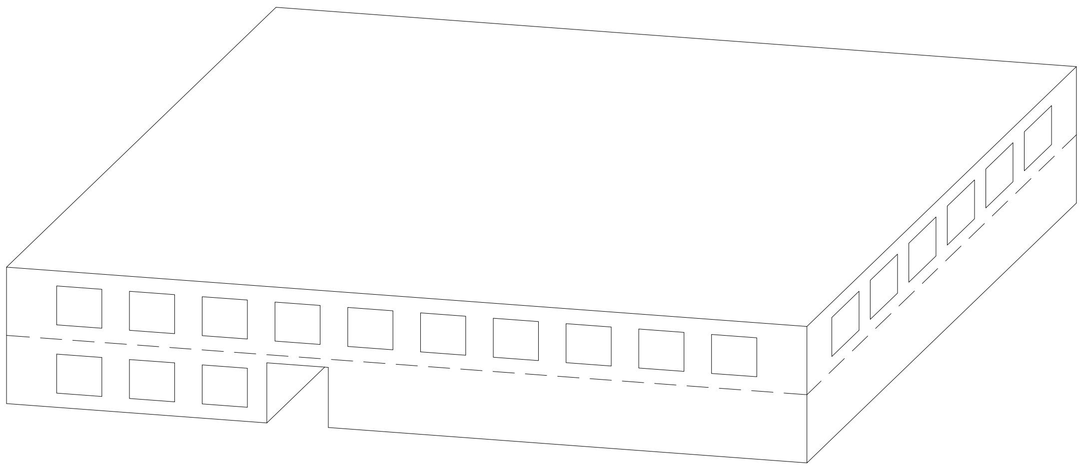


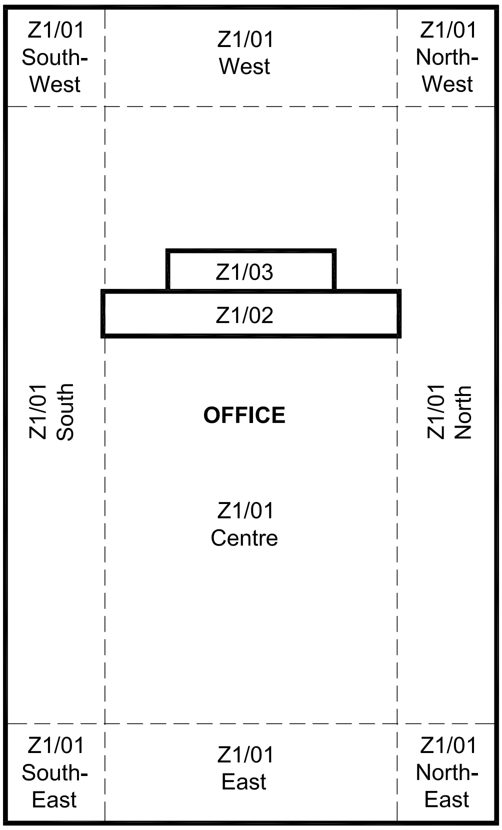


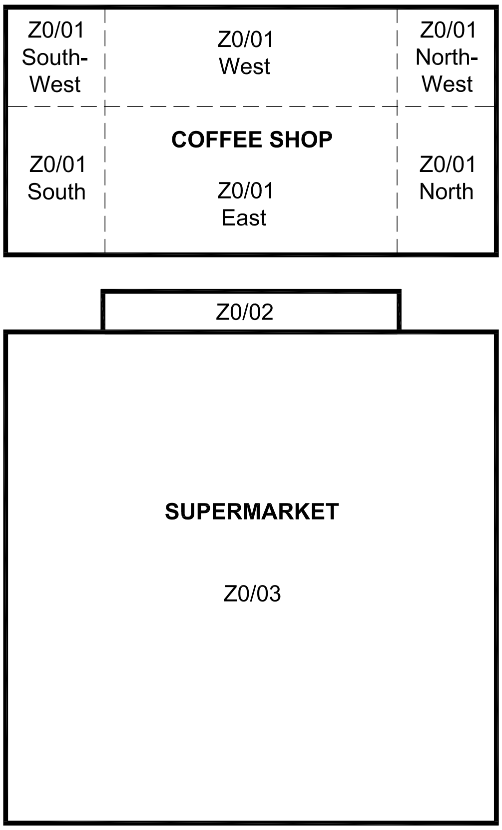
Example 1 Large Open Span Metal Clad Building
Details Of SBEM Data Entry

	WAREHOUSE	OFFICES/CANTEEN etc
heating system		
heater type	flued radiant	central heating using radiators
heat source	radiant heater not in the ECA list	LTHW boiler not in the ECA list
fuel	natural gas	
generator seasonal efficiency	0.70	0.75
system adjustment	none	
control corrections	none	
DHW	same as central heating	
zonal ventilation	natural	
lighting system		
light type	metal halide	T8 fluorescent
local manual switching	no	yes
photoelectric controls	switched	n/a
occupancy sensing	none	
provision for metering	none	
parasitic power	1.0	n/a
building envelope U-values		
metal walls	0.35	
brick walls	0.35	
internal walls	1.7	
roof	0.25	
ground floor	0.25	
internal floor	0.25	
vehicle doors	0.7	
personnel doors	1.61	
windows		
U-value	2.2	
T-solar	0.68	
L-solar	0.7	
window transmission factor	0.8	
window surface area ratio	1	
rooflights	2.2	
U-value	0.55	
T-solar	0.55	
L-solar	1	
rooflight transmission factor	1	
rooflight surface area ratio		
airtightness	10	
thermal bridges	default values	

Example 2: The 'Example Building' Used In The Tutorial Published With SBEM







Appendix 5
Detailed results from SBEM

Fig A5.1 shows the main SBEM results screen, under the "Ratings" tab and "Part L check" subtab. Fig A5.2 shows more detailed results, shown under the "Ratings" tab and "Asset rating" subtab. These two figures show the data for the first example building analysed (see Appendix 4), with 20% rooflight area.

Note that both screens show the overall CO_2 emissions for the notional building, ie 29.23 kg CO_2/m^2 per annum for this example, and the performance of the actual building (BER) ie 29.17 kg CO_2/m^2 per annum for this example.

The "Part L check" screen in Fig A5.1 also shows the TER (in this example this a 23.5% saving over the notional building i.e. 22.36 kg CO_2/m^2).

The "Asset rating" screen in Fig A5.2 shows a 'rating', which is the overall CO_2 emissions of the actual building compared to the notional building, expressed as a percentage – so this value would have to be less than 76.5% in order to achieve the 23.5% target saving (TER). In this case, since the building was modelled as closely as possible on a 2002 notional building, the performance of the actual and notional buildings are very similar, with a rating of 100% and no saving towards the TER, thus not meeting the savings required by AD L2A.

Figure A5.1

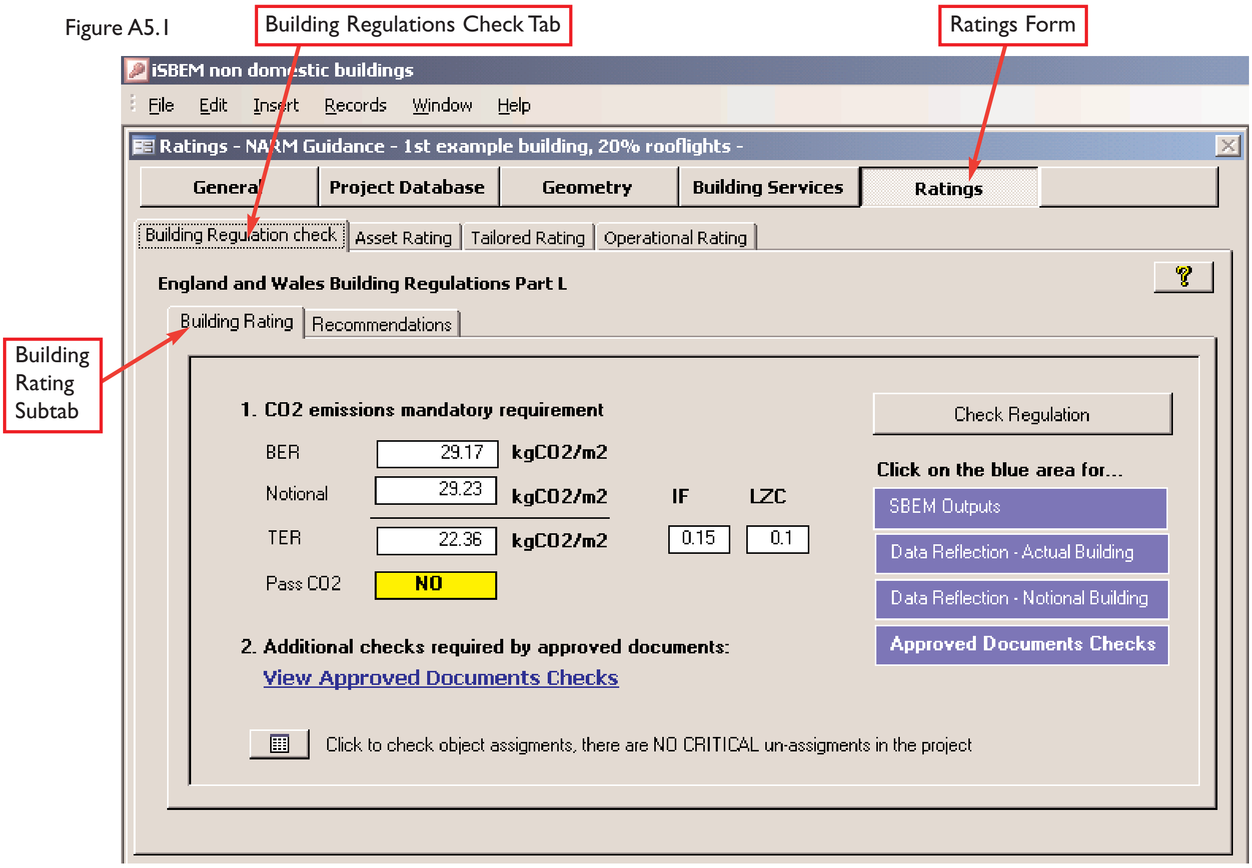


Figure A5.2

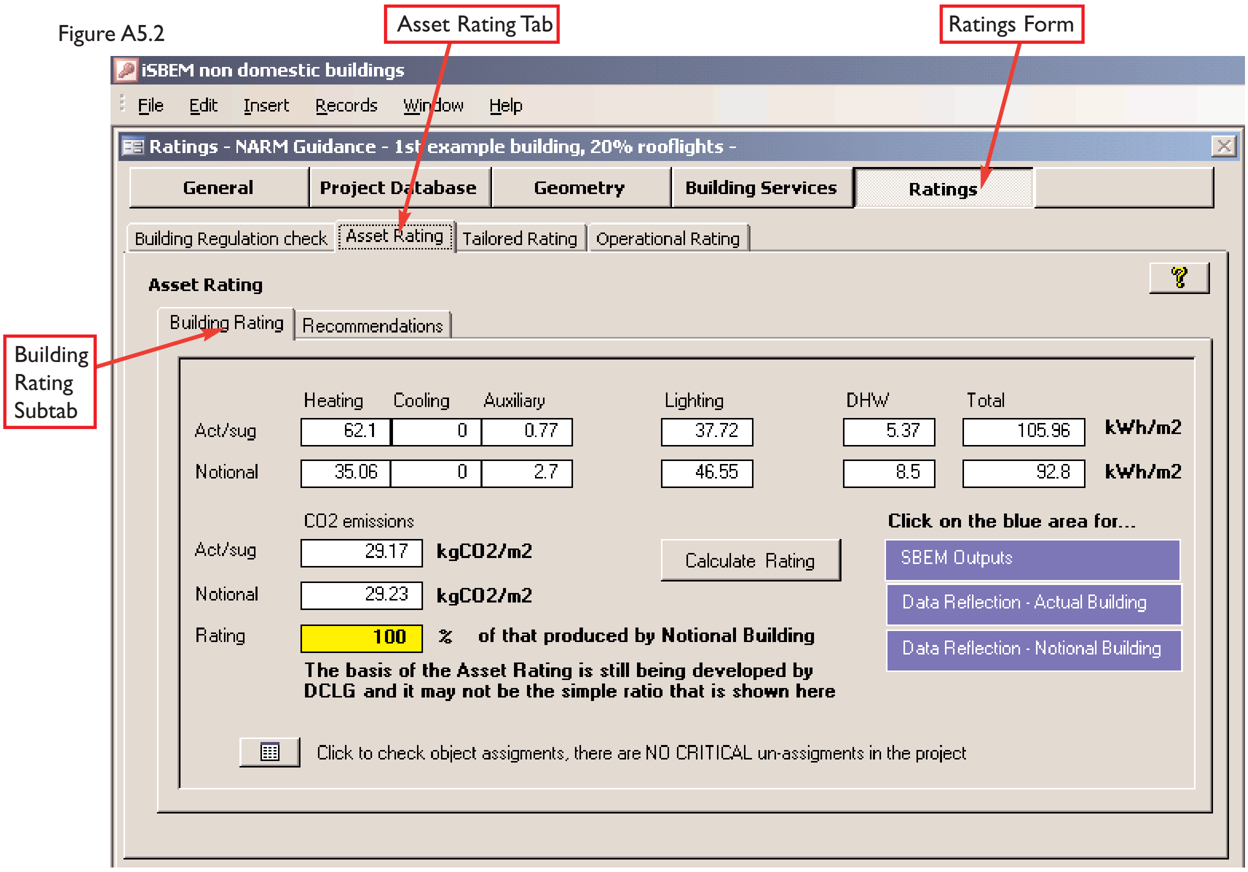
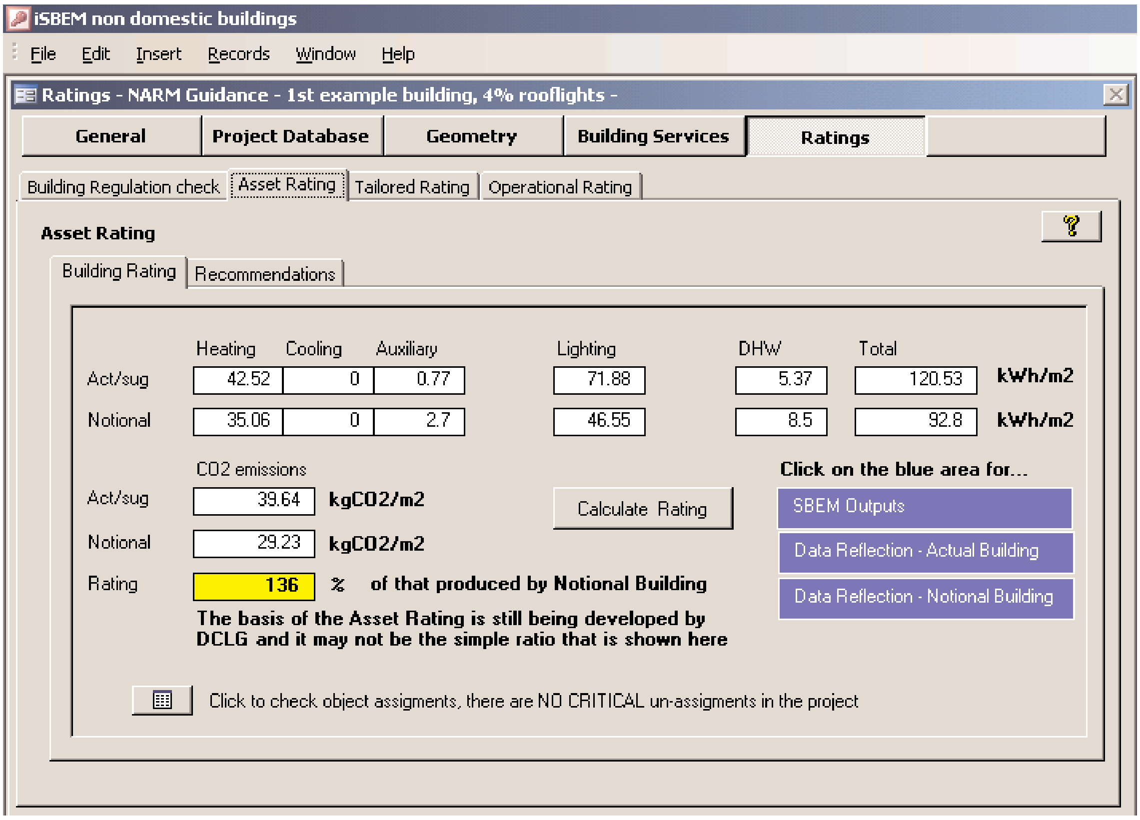


Figure A5.3



The "Asset rating" screen in Fig A5.2 also shows the energy use of the heating and lighting systems for the actual building (62.1 and 37.72 kWh/m² per annum respectively) for this example. These values can be converted to kg CO_2/m² per annum using the conversion factors shown in AD L2A Table 2 for the appropriate fuels (in this case, a factor of 0.194 for the heating, which is fuelled by natural gas, and 0.422 for the lighting, which is fuelled by grid supplied electricity).

AD L2A Table 2 CO_2 Emission Factors (Extract)	
Fuel	CO_2 emission factor kg CO_2/kWh
Natural gas	0.194
Coal	0.291
Oil	0.265
Grid supplied electricity	0.422
Biomass	0.025

The CO_2 emissions for the heating system for the example shown in Figure A5.2 are therefore 12.05 kg CO_2/m² (62.1 x 0.194) and the CO_2 emissions for the lighting system for this example are therefore 15.92 kg CO_2/m² (37.72 x 0.422). The heating and lighting curves shown in Figure 1 equate to these values at 20% rooflight area.

Figure A5.3 shows the asset rating screen for the same example building, but with rooflight areas reduced to 4%. It shows that by omitting rooflights:

- overall heating requirement has reduced to 42.52 kWh/m², equivalent to 8.25 kg CO_2/m²
- overall lighting requirement has increased to 71.88 kWh/m², equivalent to 30.33 kg CO_2/m²
- overall CO_2 emissions for the actual building (ie BER) have increased to 39.64 kg CO_2/m²
- rating has increased to 136%

The curves for heating, lighting and total CO_2 emissions shown in Figure 1 equate to these values at 4% rooflight area.

Figure A5.4

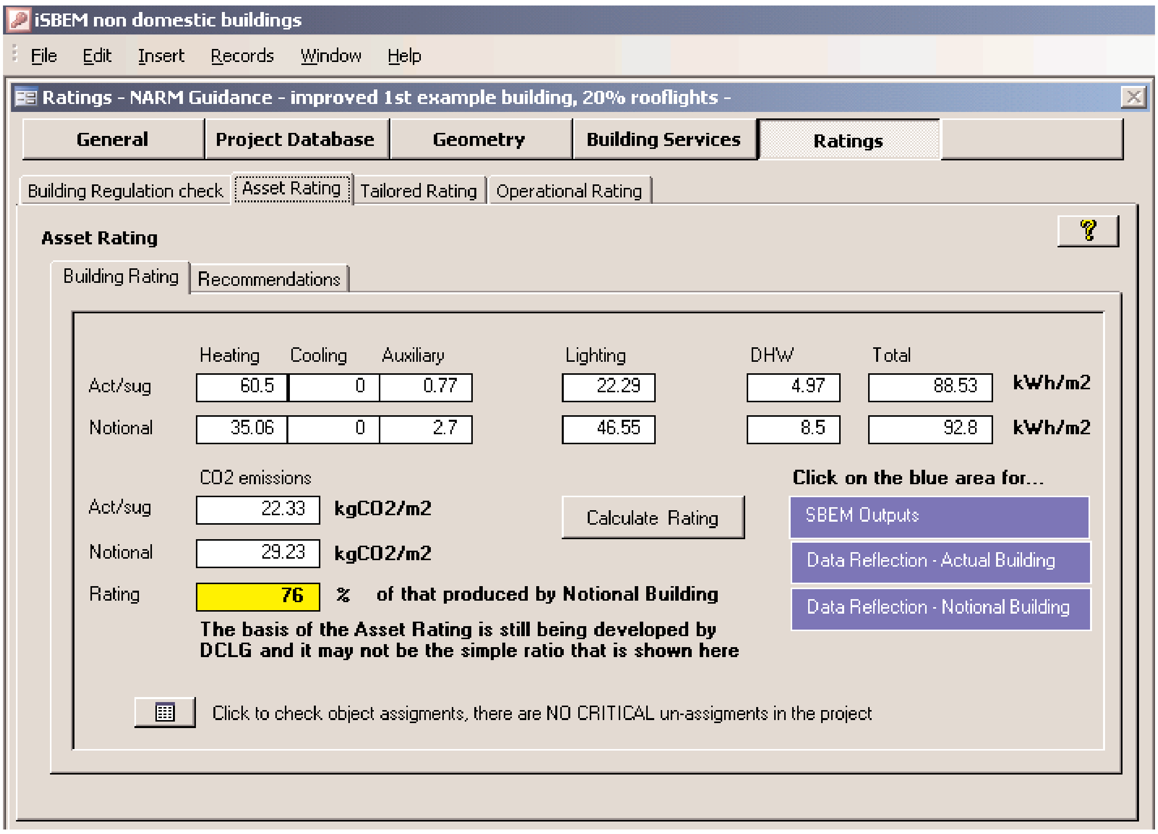


Figure A5.5

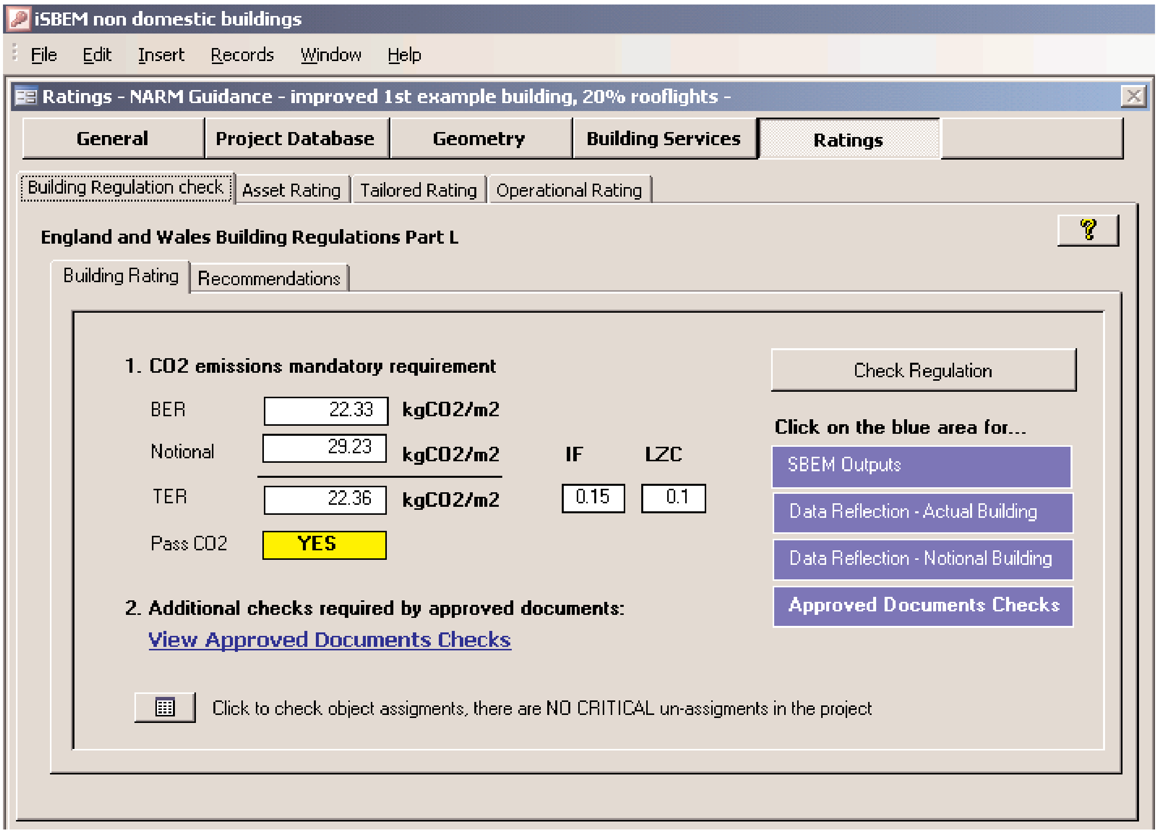


Figure A5.4 shows the asset rating screen, and Fig A5.5 the "Building Regulations check" screen, for the improved building for which results are shown in Figure 2. These screen prints show results with 20% rooflights, showing the actual CO_2 emissions (BER) of 22.33 kg CO_2/m^2, a saving of 23.6% compared to the notional building, thus exceeding the TER and achieving compliance with Criterion 1 of AD L2A.

The curve for the improved building in figure 2 equate to this volume at 20% rooflight area.

Figure A5.6 shows data for the second example building, which is the SBEM tutorial building, when modelled with rooflight areas of 0, 5, 10, 15 and 20%. The results shown in Figure A5.6 are plotted graphically in Figure 3.

Figure A5.6

Rooflight area	0	5	10	15	20
heating CO_2	3.01	3.46	4.03	4.44	4.87
lighting CO_2	40.70	37.54	34.84	33.46	32.22
tot CO_2	81.71	79.14	77.28	76.89	76.7

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