



Education
Funding
Agency

EFA daylight design guide

Departmental advice

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Summary

About this departmental advice

This is departmental advice from Education Funding Agency. This advice is non-statutory, and has been produced to help school lighting designers involved in the design of new schools understand climate based daylight modelling.

Expiry or review date

This advice will be reviewed by March 2015.

Who is this advice for?

This guidance is for:

- building services engineers, architects and lighting designers
- school client bodies

1. Introduction

Good quality daylight within the learning environment is essential. The aim of the daylight design should be to ensure sufficient levels of balanced glare-free light to all teaching spaces.

Historically daylight factors have been used to determine the quantity of light available within a room. However in practice this has led to a blinds down lights on situation. This is largely due to the simple overcast sky model used in the daylight factor calculation.

What is required is a numerical approach which supports the principles of good daylight design and good architectural design. Climate Based Daylight Modelling (CBDM) aims to provide the required numerical approach to support good design.

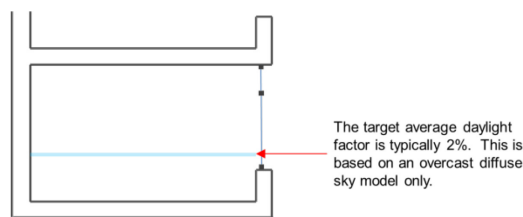


Figure 1: target average daylight factor

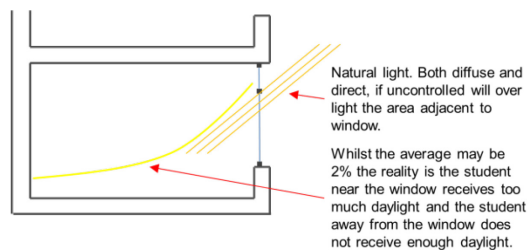


Figure 2: typical daylight factor distribution

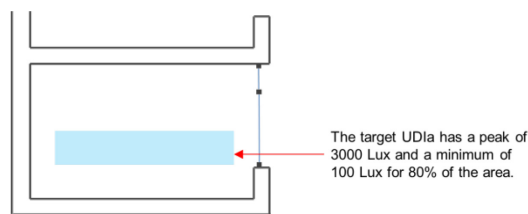


Figure 3: CBDM UDIa target

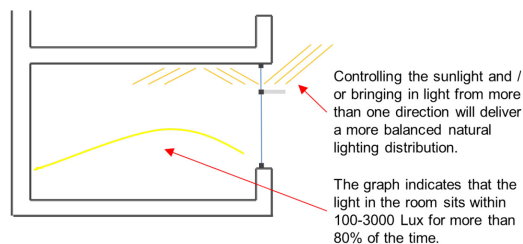


Figure 4: typical CBDM UDI-a distribution

2. Lighting metrics: DA and UDI figures

Lighting metrics: sDA and UDI figures, their definition and interpretation

Climate Based Daylight Modelling¹

The Priority School Building Programme (PSBP) output specification has a very different approach to daylight design compared with previous building programmes and school design guides.

In the past, designing for daylight within the learning environment has been a numerical process based on a static overcast sky. The ambition was to deliver a certain percentage of diffuse light into the space (daylight factors) and achieve a degree of uniformity. In reality the result was often as in [figure 2](#) with a low light level at the rear of the space and a very high level adjacent to the windows.

The EFA's PSBP output specification requires the use of Climate Based Daylight Modelling (CBDM) which takes account of the quality and quantity of sunlight and daylight. This methodology is described in brief in CIBSE's 'Lighting Guide 5' and the DfE baseline lighting strategy but has been written about at length by John Mardaljevic, Professor of Daylight Design at Loughborough University.

The introduction of these new metrics has led to daylight design becoming a fundamental part of the architectural design in PSBP. As such, daylight designers need to be consulted on massing, orientation and façade optimisation at the earliest stages of design even before detailed analyses are carried out.

Using CBDM in place of daylight factors provides far greater detail about light distribution and intensity which allows the building design to be adjusted to maximise the use of sunlight and daylight. Real weather data are used to calculate lux levels and targets can be set which are relative to user needs. Also the CBDM criteria sets a peak acceptable illuminance which reinforces the need to provide suitable glare control which modulates the light transmission rather than eliminating the light.

The daylight levels achieved using CBDM are similar to those shown in [figure 4](#). This is a much more comfortable visual environment than that shown in [figure 2](#).

For the PSBP output specification, 2 criteria have been specified, Useful Daylight Index (UDI) and Daylight Autonomy (DA).

¹ The concept of CBDM has been around for a number of years and has been used on other types of buildings, the concept was also introduced in the Society of Light and Lighting's (SLL) 'Lighting Guide 5 – Lighting for Learning'.

UDI is defined as the annual occurrence of illuminances across the work-plane that is within a range considered 'useful' by occupants. This is subdivided:

- UDI-a (x to y lux) where daylight is acceptable and electric lighting wouldn't be needed for the majority of the day; achieving a high UDI-a percentage signifies the space is predominantly daylit throughout and glare is controlled
- UDI-e (above y lux) where the amount of daylight would be considered excessive and a source of glare and the blinds would need to be operated
- UDI-s (below x lux) where the light would be considered insufficient without electric lighting

The output specification sets a minimum target of an average of 80% UDI-a for each learning space, sports hall and exam area.

There is some debate about the best range to use for UDI as daylight can be useful up to as high as 5,000 lux depending on the activities taking place. The facilities output specification (FOS) when first published used a UDI-a of 100 to 2,000 lux. The current FOS uses an FOS of 100 to 3,000 lux. Where the lighting designer believes the upper limit should be higher and will not introduce discomfort or disability glare then this can be raised.

Only the 100 to 3,000 lux range is a FOS requirement. However as 300 lux is the target illuminance in most classroom spaces then it is also appropriate to test for 300 to 3,000 lux. The higher this second figure is the better the distribution of daylight across the space. The working plane should be considered as the desk/bench height. The area boundary of 500mm from walls may be excluded from the calculation unless it is known that the task area will be around the perimeter, eg in some science classrooms.

In addition, an activity based specification can be preferable sometimes to room-based criteria as all classrooms and other teaching spaces do not contain the same range of activities and the activities vary from place to place within teaching spaces.

DA is the amount of time a space can expect to reach a target illuminance level on the working plane. This criterion is aimed at delivering an energy efficient space. The output specification sets a minimum target DA of 50% of the time for 50% of the working plane for each learning space, sports hall and exam area. The target illuminance is generally 300 lux in teaching spaces.

When undertaking UDI and DA analysis, the calculation grids should relate to the use of the space and where known the furniture layout. If a space is flexible then the calculation grid should reflect that. Where it is known that desks or working areas will not be directly against walls then a 500mm perimeter zone in each room can be eliminated from the calculation area.

Interpretation of UDI-a 80% results

The ideal scenario would be to achieve 80% UDI-a at each point in a space as this would indicate good daylight levels throughout the space.

The FOS requirement is to achieve the UDI-a as an average of the readings across the space. However in this case it is possible to achieve the rating without achieving good daylight distribution over the working plane area. In order to assess the light distribution another metric is needed. Possible metrics to assess uniformity are the minimum UDI-a value, UDI-a over the range 300 to 3,000 lux and the percentage of the points which are below 80% UDI-a. The minimum would indicate if there is an area which is not really benefitting from access to sunlight and daylight. The percentage of the area would indicate if the low levels of daylight are only in a small area of the space or beginning to dominate the space.

This is illustrated by the example below of 2 rooms with the same UDI-a but very different daylight distribution.

Example 1	Example 2
Average UDI-a = 80%	Average UDI-a = 80%
Minimum UDI-a = 75%	Minimum UDI-a = 30%
Percentage <80% UDI-a = 30%	Percentage <80% UDI-a = 25%

Table 1: example of 2 rooms with the same UDI-a but very different daylight distribution

From the average UDI-a both cases look satisfactory. However the minimum in case 2 and the percentage of area below UDI-a highlight that the daylight is not well distributed within the space.

Going beyond the basic requirements of the FOS

Although we have moved from Average Daylight Factor and Uniformity Ratio to the better metrics of DA and UDI, we are keen that daylight quality is considered alongside quantity. To this end the FOS requires designers to provide daylight from 2 or more directions into a space where possible for example by the use of clerestories, internal glazing, light slots, light wells, and roof lights. The baseline designs had light slots and internal glazing at the back of classrooms on north facing elevations; and light shelves on the south to bounce light deep into the space.

Shading and light redirecting devices

There is an art in daylight design and the choice of shading devices whether they are part of the built form or moveable devices. A moveable device under the control of the users may be preferable to a fixed element that the building user cannot move if this interrupts their views out on the other hand a moveable device requires active operation by the

building users which may not happen. Where a blind is used for the control of glare or to meet the CBDM targets then there needs to be as a minimum a narrative on how often the blind will need to be operated through the school year and how it needs to be operated. The view out needs to be considered and as far as possible shading devices should prevent glare whilst preserving an adequate view out. It should also be remembered that a roller blind can cut out both the view and the natural light and this may bring on the electric lights.

Dimout/grey out and black out blinds

Black out is required in science rooms where physics experiments will be carried out, perhaps in a third of general labs or science studios, and in every specialist lab. Black out is also required in drama spaces and in the main hall.

This can be provided by curtains but more usually in science black out (needed in physics specialist rooms) is achieved by using black – totally opaque – roller blinds sliding in channels down the sides. It is not total darkness as some light enters around the top and bottom of the opening so it is still possible to move around safely in the room.

Grey out (useful in general science rooms but insufficient for some optics experiments like mixing coloured lights) is achieved using slatted or venetian blinds – again set in box shaped channels at the sides. This produces dim light levels.

Dim-out may be needed where legacy data projectors are used. If the school will be using ultra-short throw daylight projectors that are recommended for future purchase then this will not be necessary and a higher lux level will be acceptable. There is a possible trade off here that can be discussed with the schools at single preferred bidder stage.

It may be necessary to provide shading to prevent solar glare affecting the visibility of display screens, eg on any whiteboard or ICT screens. However, it should be assumed that laptop screens can be moved to eliminate the worst glare when used near windows.

Where dim-out blinds are used no narrow slots of sky should be visible which would be distracting and a high source of glare.

Sports halls

Sport in schools should be undertaken under daylight and not in a black box environment. Furthermore the lighting load for sports halls is high and as such the target should be to illuminate the space with daylight alone. It is also important to note that many sports halls are used for exam purposes.



Image 1: North West Kent College, national standard badminton courts, Mott MacDonald

CBDM modelling and analysis

The modelling and analysis can be undertaken using a number of different software packages. Radiance is the calculation engine used to undertake the analysis. This can be used as originally intended or with a front end such as DIVA or Daysim. Daysim includes the required parts of Radiance automatically.

You will also require a modelling package to build the models to be analysed. AutoCAD, Ecotect, Rhino, Blender and Sketchup are commonly used to build these models. The models need to be as simple as possible whilst containing the key information on which daylight performance depends.

The accuracy of the model, as would be expected, plays a significant role in the accuracy of the results. A number of key points are listed below:

Wall thickness: this must be modelled including any window ledge or overhang.

Window detail: the transmittance of the glazing is important for the accuracy of the model. Equally important is the modelling of the window frame. It is not sufficient to allow a light loss factor of say 15%. The depth, height and reflectance of the window frame is critical.

Internal details: items such as acoustic panels, ductwork, downstands, window reveals, light shelves and blinds need to be included in the modelling as they will adjust the distribution of light.

Reflectance: these must match the design and be supported with data from the paint supplier or carpet manufacturer etc. Where a combination of vinyl and carpet is used the floor model should reflect the locations and areas of different materials. A white ceiling will benefit the daylight distribution within the room. At the early design stage when furniture layouts and floor reflectances may not be known a floor reflectance of 0.2 can be used and the room should be reviewed without any furniture to enable an

understanding of the distribution of daylight through the space. At detailed design stage the actual room layouts and furniture and floor reflectances can be used to fine tune the design.

External obstructions: as CBDM uses sunlight and daylight then external obstructions need to be modelled. Equally, orientation is very important.

Weather data: the most readily accessible weather data is from the Energy Plus website. Energy Plus Weather Data. Energy Plus Weather Data. Other weather data is available such as that from CIBSE. It has been successfully used but care should be taken by the end user to validate the data set.

Analysis parameters

Hours of operation: 8:30am until 4pm (full year data including weekends and holiday periods should be used).

Time Step: 5 minutes

Grid Size: <250mm square

Grid Location: Working plane height suitable for the task.

Experience

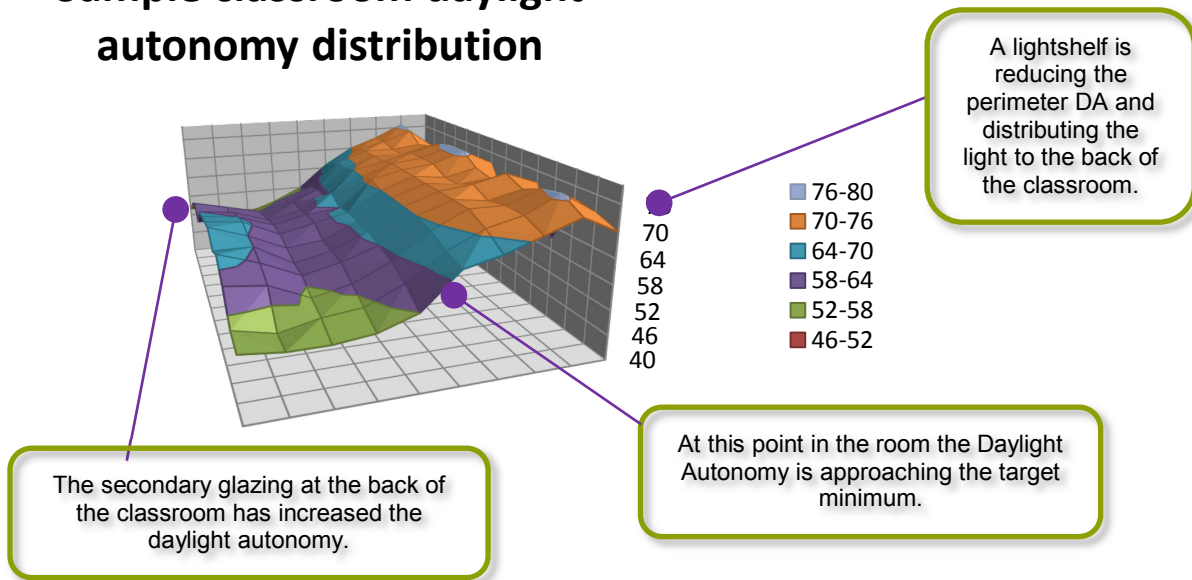
Undertaking daylight design work has never been a simple task to get right and CBDM requires a greater understanding of the subject of daylight. The software requires a period of research and testing to become familiar with the process and output. It takes some considerable lighting design experience to use these programmes effectively as part of an iterative design process working with the architect, acoustician and ventilation designer to inform the architectural design. The challenge for the contractors is to do this quickly and effectively to inform their standard geometries.

3. Baseline designs

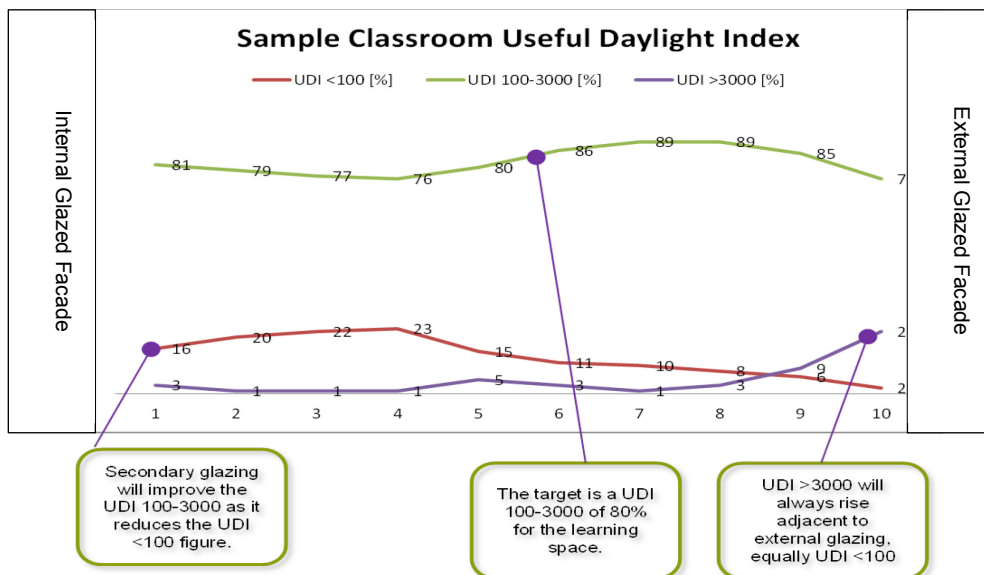
Daylight analysis results

The graphs below show the modelling results obtained for the baseline design classrooms.

Sample classroom daylight autonomy distribution



Graph 1: sample classroom daylight autonomy distribution



The sample graph here shows the results of a UDI analysis for a classroom. Each line represents the results as if a line had been drawn down the centre of the room from the external window to the back wall. A 3D graph would provide further detail.

Graph 2: sample classroom useful daylight index

4. Surface colours and light reflectances

Ceilings

Ceilings with exposed concrete surfaces to provide thermal mass in schools should be painted matt white as this provides good light reflectance. The paint finish should not be reflective, ie gloss as this will reduce the emissivity and hence the ability of the ceiling to absorb heat by radiation. The emissivity of the paint finish should be at least 0.85.

Furniture and window surrounds

The PSBP FOS requires that the gloss factor of window sills, furniture and flooring is less than 15%. This information can be sourced from the manufacturers of the window sills, furniture or floor coverings.

The gloss factor is different to reflectance and the two must not be confused. A highly reflective material with a matt or diffuse finish is beneficial in delivering light within an internal space. However high gloss surfaces (specular) are likely to give rise to discomfort glare. Sunlight and daylight can be reflected from specular surfaces such as window sills with a high level of intensity and direction towards the internal occupants.

Floor finishes

When selecting floor finishes it is necessary to achieve a balance between the benefit of daylight and the operational needs of cleaning and maintenance.

The 'SSLD Guidance Note 2: Floor Finishes in Schools' provides detailed guidance on the choice and installation of floor finishes.

The latest PSBP FOS paragraph 2.7.18.5.3 requires a minimum floor reflectance of 0.2 for all habitable rooms and states that where areas of the room are carpeted the average surface reflectance of the floor can be reduced to 0.07.

In addition FOS paragraph 2.7.18.6 requires that the floor finishes have a surface reflectance not higher than 0.4 to avoid scuff marks.

However 20% floor reflectance is almost always used as the standard in lighting calculations. This is generally used to assess unfurnished rooms and when furniture is in position this generally as a higher surface reflectance than 0.2 so that this does compensate for a lower floor reflectance.

The following worked example is intended to give an idea of what carpets are available and inform the discussion around compliance.

Example

The Light Reflectance Values (LRV) information from [Desso Airmaster carpet tiles](#) for educational purpose is used to demonstrate compliance of the technical requirements with the FOS only. The LRV scale runs from 0, which is a perfectly absorbing surface that could be assumed to be totally black, up to 100, which is a perfectly reflective surface that could be considered to be the perfect white.

Step 1: identify the LRV

In this working example there are three carpet tile options with an LRV nearing 20, ie 18.74, 17.05 and 18.07

Step 2: the colours they represent

18.74 – colour 1958

17.05 – colour 2914

18.07 – colour 9504

The results are mid to light tones – not the very dark colours which often get presented and are perceived a practical solution because they don't show the dirt.

Product name: **Airmaster**

Results:

Colour	L*	LRV
1958	50.37	18.74
2914	48.32	17.05
3118	20.75	3.18
3211	24.22	4.17
3023	31.60	6.87
4208	29.08	5.87
4307	20.22	3.04
4406	36.61	9.33
4407	19.56	2.88
7218	20.31	3.07
7311	33.79	7.91
8208	20.16	3.03

Colour	L*	LRV
8412	33.47	7.76
8501	24.31	4.19
8508	19.97	2.98
8811	20.53	3.12
8902	23.38	3.91
9084	36.59	9.32
9091	19.16	2.79
9104	26.94	5.07
9502	28.93	5.81
9504	49.58	18.07
9511	19.61	2.89
9522	33.06	7.57

Tiles (24)

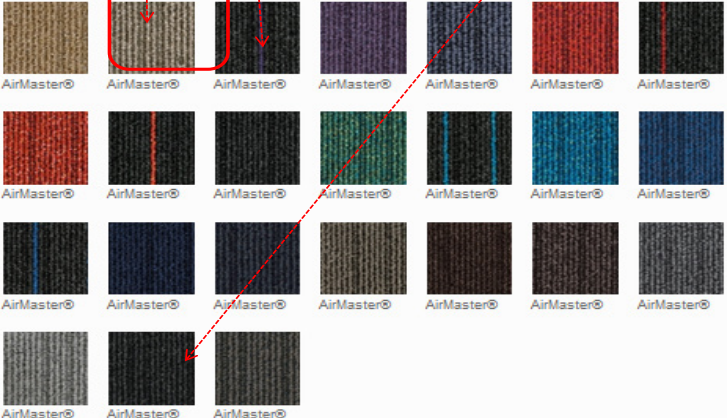


Image 2: Desso Airmaster carpet tiles

Further information

Useful resources and external organisations

- [‘Lighting Guide 5: Lighting for Education’](#) (LG5) published by the Society of Light and Lighting gives a comprehensive guide to lighting for building services engineers.

Other relevant departmental advice and statutory guidance

- [Guidance on lighting design for schools](#)

Other departmental resources

- [Baseline designs and strategies for schools](#)



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