A ROADMAP FOR UPGRADING NATIONAL/EU STANDARDS FOR DAYLIGHT IN BUILDINGS

Mardaljevic, J.[1] and Christoffersen, J.[2]

[1]School of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK
[2]VELUX A/S, Ådalsvej 99, DK-2970, Hørsholm, Denmark
[1]j.mardaljevic@lboro.ac.uk

Abstract

It is now widely accepted in the research community, and increasingly so amongst practitioners, that the standards/guidelines for daylight in buildings are in need of upgrading. The basis for the majority of EU guidelines is the half-century-old daylight factor. The daylight factor (DF) considers relative illumination under a single overcast sky. Thus the DF is insensitive to prevailing climate and orientation of the building or site. Attempts to advance standards beyond the daylight factor have, so far, met with limited success. There are a number of reasons for this, one of the most significant being that, with one largely overlooked exception, it appears to be impossible to advance the DF methodology by incremental means. The incremental advances that have been suggested include the various ‘clear sky options’ described in LEED and ASHRAE. The basis for these approaches appears to be flawed if not actually unsound. It is now widely acknowledged that climate-based daylighting modelling offers the means to make a major advancement in the evaluation of daylight in buildings. Climate-based daylight modelling (CBDM) delivers predictions of luminous quantities under realistic sun and sky conditions. Climate-based metrics have been used effectively on a number of projects large and small, e.g. from the New York Times Building to residential dwellings. CBDM tools however are either the preserve of research/experts or freely-available but largely unsupported. Whilst metrics founded on CBDM will almost certainly form the basis for daylight standards in the medium term (some are already appearing), there is a pressing need to progress current practice in the short term, i.e. the next few years. Specifically, the authors propose that a long-overlooked method linking the estimation of daylight provision to prevailing climate be used as the basis for guidelines and standards. The method, founded on cumulative diffuse illuminance curves, could be introduced relatively swiftly since it requires only modest enhancement of existing daylight prediction tools. And, importantly, it will provide a sound ‘footing’ for eventual progression to evaluations founded on full-blown climate-based daylight modelling.

1 Introduction

Towards the end of 1990s the daylighting of buildings began to achieve greater attention than had previously been the case. There were a number of reasons for this, but the two most important ‘drivers’ were:

a) the widespread belief that the potential to save energy through effective daylighting was greatly under-exploited; and,

b) the emergence of data suggesting that daylight exposure has many positive productivity, health and well-being outcomes for building occupants.

The first originated with the widely-accepted need to reduce carbon emissions from buildings in order to minimise the anticipated magnitude of anthropogenic climate change. This in turn led to the formulation of guides and recommendations to encourage the design and construction of ‘low energy’ buildings and also for the retrofit of existing buildings. All these guides contain recommendations on daylighting, invariably founded on the daylight factor or an equally simplistic schema such as glazing factors [16]. The second driver was the gradual accumulation of data from disparate sources on the non-visual effects of daylight exposure. These effects are believed to be wide-ranging and include productivity and health/well-being, e.g. academic achievement, retail sales, recovery in hospitals, entrainment of circadian rhythm, etc. The mechanisms for these effects are not yet fully understood, and it is not yet known what the preferred exposure levels should be, though it seems likely that existing guidelines would be ineffective for the evaluation of these quantities [1]. Nonetheless, given the still relatively low cost of electric lighting – and the potential for it to be further reduced with solid-state lighting – there is evidence to suggest that the cost benefit from increased productivity due to good daylighting could be far greater than the cost saving from reduced energy expenditure [7]. Thus the second of these drivers has been promoted on both economic *and* environmental quality grounds.

2 Guidelines, compliance schemes and the challenges ahead

One of the earliest recorded recommendations for what we now call climate-adapted building design is that attributed to Socrates [469–399BC]:

> *Now in the houses with a south aspect, the Sun's rays penetrate into the porticoes in the winter, but in summer, the path of the Sun is right over our heads and above the roof so that there is shade. If, then, this is the best arrangement, we should build the south side loftier to get the winter sun and the north side lower to keep out the cold winds.*
>
> Quoted by Xenophon in *Memorabilia Socrates*

Over the following two thousand years numerous architectural styles evolved across the globe in response to the specific cultural/societal imperatives, and driven by advances in building technology and construction techniques. Daylighting design remained a rule-of-thumb practice, informed by tradition and internalised knowledge about what was known to work for that particular climate and locale. Building apertures were rarely designed for the sole purpose of providing daylight illumination since protection from the hot and cold extremes of the prevailing climate was also an important design concern.

By the late 1800s the pressure to accommodate an increasing number of people in the cities of the developing world led to taller and more tightly-packed building forms, thereby reducing and often eliminating entirely the direct view of sky from much of the useable, internal space. This in part led to the need for some objective measure of the daylighting performance of a space which could, if required, function as a tool to evaluate buildings at the planning stage. Daylight was at that time still the preferred source of illumination for both manual and clerical work.

2.1 The daylight factor

It appears that the daylight factor, or at least its precursor, was first proposed in 1895 by Alexander Pelham Trotter (1857-1947) [12]. The origins of the daylight factor are actually somewhat hazy since there does not appear to have been a seminal paper introducing the approach. The reference to its introduction in 1895 appears to be anecdotal and recalled a number of years later. The daylight factor was conceived as a means of rating daylighting performance *independently* of the actually occurring, instantaneous sky conditions. Hence it was defined as the ratio of the internal horizontal illuminance E_{in} to the unobstructed (external) horizontal illuminance E_{out}, usually expressed as a percentage:

$$DF = \frac{E_{in}}{E_{out}} 100\% \tag{1}$$

However, the external conditions still need to be defined since the luminance distribution of the sky will influence the value of the ratio. At the time that the daylight factor was first proposed it was assumed that heavily overcast skies exhibited only moderate variation in brightness across the sky dome, and so they could be considered to be of constant (i.e. uniform) luminance. Measurements revealed however that a densely overcast sky exhibits a relative gradation from darker horizon to brighter zenith; this was recorded in 1901. With improved, more sensitive measuring apparatus, it was shown that the zenith luminance is often three times greater than the horizon luminance for some of the most heavily overcast skies [17]. A new formulation for the luminance pattern of overcast skies was presented by Moon and Spencer in 1942, and it was adopted as a standard by the CIE in 1955. Thus, since 1955, the daylight factor is strictly the ratio of internal to external illuminance determined under a sky luminance distribution that conforms to the CIE Standard overcast sky pattern:

$$L_\theta = \frac{L_z \left(1 + 2 \sin\theta\right)}{3} \tag{2}$$

where L_θ is the luminance at an angle θ from the horizon and L_z is the zenith luminance. However, there may be good reason to consider the CIE standard overcast sky as an "extreme" type of overcast sky with a lower occurrence in the gamut of overcast skies than is generally expected or assumed [5][14]. Notwithstanding the recent questionings regarding the validity of the CIE standard overcast pattern as the sole basis for the quantitative evaluation of daylight, it remains the most commonly used sky in guidelines and recommendations.

Many guidelines give an average daylight factor as the recommended target. For example, in BS8206-2 the guidance states that to "have a predominantly daylit appearance . . . [the] average daylight factor should be at least 2%” [2]. In a similar vein, the Building Research Establishment Environmental Assessment Method (BREEAM) states that “. . . at least 80% of floor area in occupied spaces has an average daylight factor of 2% or more” [3]. These guidelines can have a major influence on key aspects of the building design. For example, school buildings with a significant element of prefabrication have been designed to conform to BREEAM daylight specifications, Figure 1 [10].

Figure 1: Prefabricated school building with classrooms designed to BREEAM daylight factor specification [from CIBSE Journal, June 2011]

Note however that, even with something as seemingly straightforward as an average daylight factor specification, the results are open both to interpretation and ‘game-playing’. Consider the example classroom shown in Figure 2. The dimensions are 6m $\times$ 7m $\times$ 2.7m (width $\times$ depth $\times$ height), with a glazing height of 1.9m. The falsecolour image shows the predicted daylight factors across a sensor plane (at desk height) that covers the entire floor area. Table 1 shows the variation in predicted average DF for border widths around the sensor plane varying from 0 to 1m. The average DF for this (quite highly glazed) space is very sensitive to the border width, but note how insensitive the median is to this variation. Furthermore, the average tells us nothing about the distribution of DF in the space, whereas the median does. The average can be a quite misleading quantity when applied to daylight distributions, especially for spaces illuminated from vertical glazing on one wall where the very high DFs close to the windows can significantly influence the average DF value. The 2011 revision of Lighting Guide 5: Lighting for Education recommends that there is a 0.5m border width (i.e. perimeter) between the sensor points and the walls/glazing [11]. For this example, the LG5 recommendation equates to 71% of the useable floor area. However, note that LG5 is stated in terms of a *border*, whereas the BREEAM guidance recommends a percentage of the floor area for the sensor points, but not where it should be placed. Thus, with BREEAM, the user could in principle choose where to place the 80% coverage sensor plane – leading to significant variation in the outcome. An 80% coverage sensor plane ‘pushed-up’ against the glazing would result in a markedly higher average DF compared to one that was centrally placed, and greater still compared to one placed at the rear of the space. As before, the median would be far less sensitive to such placement issues.

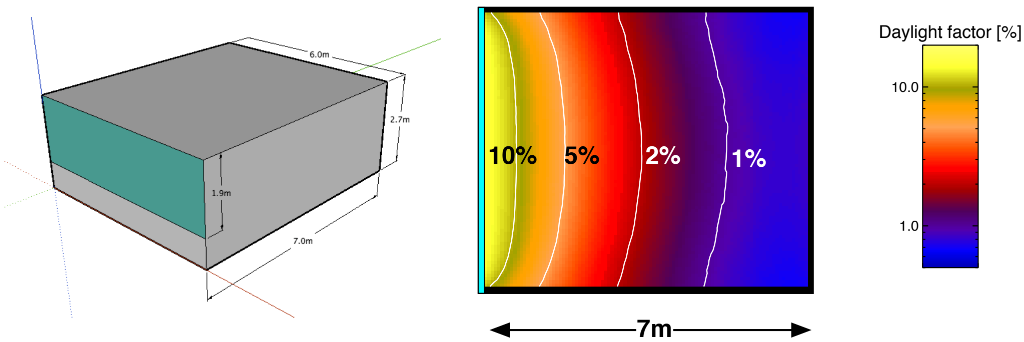

Figure 2: Daylight factor distribution in a typical side-lit, deep-plan classroom space

Table 1: Average and median daylight factors for border widths 0 to 1m

Border around sensor plane [m]	Average daylight factor [%]	Median daylight factor [%]	Percentage total floor area
0.00	3.5	1.8	100%
0.25	3.3	1.8	85%
0.50	3.1	1.8	71%
1.00	2.7	1.9	48%

2.2 The impossibility of holistic daylighting design with a 'fractured' methodology

The luminance of the CIE standard overcast sky is rotationally symmetrical about the vertical axis, i.e. about the zenith. In other words, the illumination that the standard overcast sky delivers to an internal space will be same regardless of the compass orientation of the building. And, since the sky is fully overcast, there is of course no sun. Thus for a given building design, the predicted DF is insensitive to either the building orientation (due to the symmetry of the sky) or the intended locale (since it is simply a ratio). Because the sun is not considered, any design strategies dependant on solar angle, solar intensity, or redirection of sunlight can have no influence on the daylight factor value.

In the half-century or more since the daylight factor was first formulated it has become the the dominant metric, in fact, often the sole quantitative measure of natural illumination used to evaluate building designs. An indication perhaps of the ubiquity of the daylight factor is its appearance as a measure for compliance in the most unexpected places. The daylight evaluation in the first edition of the Estidama Pearls Design System for Abu Dhabi was founded on daylight factors, i.e. the CIE standard overcast sky [6]. A quick examination of the standard climate for Abu Dhabi reveals that it is almost *never* overcast in that region of the United Arab Emirates. This, not unexpected observation, suggests that at least in some instances the daylight factor has indeed been applied as a matter of routine without consideration of the prevailing climatic conditions.

As noted in the Introduction, it is in fact the non-energy related considerations of daylight that are likely to have the greatest influence on building design. The studies that have claimed improved academic achievement for, say, classrooms with "good daylighting" (e.g. Heschong in 2002 [7]) have gained prominence in design circles, and are now influential when fundamental decisions regarding performance criteria are made. But, whilst the message re: 'good daylighting' is being taken notice of, the implementation is often poor if not actually counterproductive – that is, it could result in *worse* rather better daylight performance. In part this occurs because "good daylighting" is often taken to mean *more* daylight, which in turn is taken to mean *higher* daylight factors. In practice, this often results in spaces where the occupants habitually lower blinds/shades to control for visual and/or thermal discomfort – any daylight benefit is lost and the lights are usually left switched on. Such outcomes should not be too surprising because reliance on the daylight factor has not encouraged practitioners to think of the luminous environment as one that should be "well-tempered", i.e. avoiding too much as well as too little. Consider the following two criteria taken from the "Construction Requirements" for a UK hospital:

- "minimise direct solar gain to avoid the requirement for air conditioning / comfort cooling;"
- "maximise daylight factor in patient areas;"

Using the standard 'toolset' i.e. daylight factors and solar penetration / heat gain study, these two criteria are impossible to reconcile. Hardly surprising since one method uses a (single) sunless sky and the other a skyless sun.

2.3 The marginalisation of the expert daylight designer

A half-century or more of often uncritical use of the DF has unfortunately led to a conflation in many minds of actual daylighting performance with what the daylight factor tells us. The DF is of course a proxy for daylight, but how good or bad a proxy depends on those important parameters that the DF approach cannot account for: prevailing climate (meaning the totality of sky and sun conditions) and building/site orientation. The expert daylight designer does of course appreciate these intrinsic deficiencies. If sufficiently experienced, the designer can roughly guesstimate the likely daylighting performance of the space and so recommend suitable facade treatments to temper the luminous environment. Thus the expert intuits what is called the spatio-temporal dynamics of natural illumination. We of course shouldn't be surprised to learn that the designer recommends different treatments for the north, south and east/west elevations. Nor that the advice would change if the building were relocated from, say, Stockholm to Madrid. After all, 'climate-adapted design' is a notion that relates closely to vernacular architecture. The designer will probably also carry out a daylight factor analysis because it is easy to do and they can charge the client for it – even if they take minimal notice of it themselves. If however the client demands that the daylight credit from a particular guideline document (e.g. BREEAM, LEED, etc.) must be achieved, then the success of the design will hinge to a large degree on the nature of the 'target' sought - invariably some measure based on the daylight factor. In which case, the best the expert designer can do is try to make good the failings that might, and often do, result from compliance chasing. The client may even decide that the expert is not required since the facade treatment will be 'optimised' by someone using a lighting simulation tool: tweaking here and there until the compliance target is reached. This has led one notable lighting expert to conclude that:

> *". . . the only people who have a chance of getting it right are those who ignore everything the lighting profession proclaims through daylighting codes, standards and recommended practice documents."* [4]

Such sentiments are understandable. However, if the standards are proving to be insufficient to ensure a high likelihood that a good daylighting design is achieved, then we should look to improving them rather than ignoring or ditching them altogether.

2.4 'Clear sky options'

The 'clear sky option' in LEED version 2.2 appears to have been introduced as a means to overcome the limitations of the climate/orientation insensitive glazing factor and daylight factor methods. To achieve credit 8.1, the requirement can be:

> *Demonstrate, through computer simulation, that a minimum daylight illumination level of 25 footcandles has been achieved in a minimum of 75% of all regularly occupied areas. Modeling must demonstrate 25 horizontal footcandles under clear sky conditions, at noon, on the equinox, at 30 inches above the floor.* [21]

Whilst this may appear, at first, reasonable, the LEED v2.2 documentation gave no supplementary data for the evaluation. This omission all but renders the evaluation meaningless since there is no statement regarding the diffuse horizontal illuminance that the sky should be normalised against. The user, it seems, is to trust the default value that is provided by the sky generator program. The default value is an extremely coarse approximation with some latitude dependance (and of course time of day/year), but no basis whatsoever in local, prevailing climatic conditions. Many users are unaware that the key input parameter for their simulation is of dubious provenance and has been automatically selected on their behalf. It gets worse. Nor indeed is there any mention of what the sun luminance (usually derived from direct normal illuminance) should be. This too is surprising, since the sun contribution will greatly add to the illuminances resulting from the diffuse sky (which will depend on the unspecified diffuse horizontal illuminance anyway). Given the relatively modest target illuminance (around 250 lux) it seems likely that the evaluation is meant to be carried out using a clear sky distribution without a sun. Which, of course, is a physical impossibility in reality. Anecdotal evidence has confirmed that users of LEED have indeed 'demonstrated compliance' with the recommendations and obtained Daylight Credit 8.1 by using a *physically impossible* luminous environment (i.e. clear sky without sun) that is normalised to an *unknown* diffuse horizontal illuminance.

In 2009 ASHRAE standard 189.1 was produced which has a similar clear sky option to LEED, except now the user has the option to select *either* the CIE Overcast *or* the CIE Clear sky model. As with the LEED clear sky option there is no mention of normalisation and an absolute value (300 lux) is to be achieved. This offers intriguing possibilities to the artful compliance chaser, since the outcome it turns out depends to a large degree on what default values 'drop out' of the sky generator program. In some ways this is less helpful than the LEED clear sky option because, in addition to the lack of a normalisation value, the user can choose – essentially arbitrarily – between sky types. The inconsistencies with these and similar methods were discussed in a recent paper by Mardaljevic [14].

2.5 The challenges ahead

The use of daylight in office buildings is generally considered to be a greatly under-exploited resource. Numerous so-called advanced glazing systems and materials have appeared on the market in recent years. Almost all of these are designed to modulate and/or redirect beam sunlight, e.g. electrochromic glazing, interstitial mirrored louvres, etc. It is therefore effectively impossible to reliably evaluate these new systems using any method that excludes sunlight. Looking ahead, any consideration of the non-visual effects of daylight will require an analysis that considers absolute levels of illuminance in the space, accounting for the sun and skylight together [15]. There is little prospect that the current evaluative schema (i.e. daylight factors) could ever have any relevance for an evaluation of the non-visual effects of daylight.

The accurate prediction of daylight in spaces under realistic sun and sky conditions, and for many instances e.g. hourly for a full year, was first demonstrated in the late 1990s [13][19]. Now known as climate-based daylight modelling (CBDM), it is the prediction of luminous quantities founded on standardised meteorological files specific to the locale for the building under evaluation. CBDM delivers predictions of, say, internal illuminance on an hourly (or shorter) basis for a full year, accounting for the contribution from varying sun and sky conditions. Thus it models daylight how it is experienced: holistically – the illumination effect of sun and sky together. CBDM is over a decade old and has been used effectively on a number of projects large and small, e.g. from the New York Times Building to residential dwellings. Metrics founded on CBDM include useful daylight illuminance (UDI) and daylight autonomy (DA). A CBDM metric was approved by the US Illuminating Engineering Society in 2012 [9]. Called spatial daylight autonomy (sDA), the 'target' is based on the attainment of 300 lux for 50% of the analysis period (08h00 to 18h00 local time) across 55% or more of the floor area to be considered "nominally acceptable", and 75% or more of the floor area to be rated "favourably" or "preferred".

CBDM tools are however still largely the preserve of lighting simulation experts/researchers. For CBDM to become mainstream the software to do it needs to be taken up and supported by one or more major software houses. Here lies a classic 'chicken and egg' conundrum. On one hand, those who draft guidelines are reluctant to recommend metrics founded on CBDM because tools to predict the metrics are generally not available, at least not as software supported by one of the major vendors. On the other hand, the software vendors are understandably loathe to dedicate the resources to develop and maintain CBDM tools because – inasmuch as climate-based metrics are not in the guidelines – there will be no real market for these new tools. This presents something of an impasse to all those who strive to advance daylighting standards beyond the current guidelines. Furthermore there is the risk of a "skills gap" developing in daylight modelling between a small core of CBDM experts and the rest who see little prospect for developing those expert skills in-house. In other words, there is a risk that the 'head' (i.e. those with CBDM skills) could separate from the 'tail' (i.e. those without CBDM skills), leading to fragmentation in the practitioner user base and barriers to knowledge transfer. Such an eventuality would probably hinder rather than encourage general progression towards better metrics. Such eventualities should be avoided, or at least their detrimental effects mitigated, if at all possible.

3 A way forward

A possible solution to the conundrums noted above is to apply a modest enhancement to the standard daylight factor method. This will provide a 'bridge' between current practice and full-blown CBDM. And so, it is hoped, ultimately ease the eventual transition to climate-based modelling. In order to obtain 'buy-in' from all relevant stakeholders (e.g. standards bodies, designers, end-users, tool developers, etc.) it is important that all can appreciate the benefit of the changes proposed. These benefits should include: a more robust approach to evaluating daylight in buildings using existing tools with modest enhancements; a methodology that allows for later progression to more reality-based evaluations; and, a transition 'roadmap' with clear market horizons to ensure that software vendors invest the necessary resources to develop advanced tools (i.e. for CBDM).

3.1 Climate 'connectivity' in standard daylight modelling

To initiate this process, it is proposed to move the basis of daylight evaluation from relative values based on a single sky (i.e. the DF), to the annual occurrence of an absolute value for illuminance (e.g. 300 lux) estimated from the cumulative availability of diffuse illuminance as determined from standardised climate files. This is an application of an established but largely neglected approach [8]. This proposal offers several advantages. Firstly, since the estimate is derived from daylight factors, it requires only a modest enhancement to existing software tools that predict DFs. Next, it provides some 'connectivity' to the prevailing climate. A target that has been proposed for the new metric is that a side-lit design should achieve 300 lux across half of the work plane for half of the year when the sun is above the horizon. To achieve this for say, Stockholm, half of the sensor points must have a DF of 2.5% or greater, whereas for the Madrid the 'target' DF would be 1.8%. Note, the target is based on the *same* criterion for internal daylight provision, it is of course the greater prevailing diffuse illuminance for Madrid compared to Stockholm that results in the lower 'target' daylight factor for the Spanish capital. There are other advantages – the median approach informs on the spatial distribution of daylight whereas, as noted earlier, the average daylight factor value does not.

3.2 Rationale for the 300 lux target

A number of studies have demonstrated that 300 lux of natural illumination is considered adequate by the majority of building users and also correlates with the notion of a "well daylit space" [20][9]. Furthermore, design levels for artificial lighting are increasingly being set at or close to the 300 lux mark. The definition of the attainment period (i.e. half the time that the sun is above the horizon) ensures that the measure of daylighting potential estimated by this method is determined by the intrinsic building design and its intended locale, and not an arbitrary factor such as working hours which could easily change even before the finished building is occupied. The specification that half of the sensor points achieve the design goal of 300 lux for half of the daylit year (i.e. half the time when the sun is above the the horizon) provides an assured goal for the spatial distribution of daylight. Note that there is no such guarantee regarding spatial distribution of daylight using, say, an average daylight factor for a space since the average is greatly skewed by the high values close to a vertical window. Thus, whilst the average daylight factor for a space might appear "sufficient", the median value (i.e that achieved by half of the sensor points) is always markedly lower for spaces with vertical glazing (Table 1).

3.3 Prerequisites

An annual time-series of hourly diffuse horizontal illuminance data for the intended locale of the building under evaluation is required. These can be obtained at no cost from a number of on-line repositories. Following the practice long-established for dynamic thermal simulation of buildings, the standard climate dataset recorded nearest to the location of the actual/intended building is usually the most suitable for evaluation purposes.

Suitable data to describe the building under evaluation for the purpose of daylighting simulation. Namely: building geometry and dimensions; reflective properties of the opaque surfaces and transmission properties of the transparent surfaces (e.g. glazing); and, significant external obstructions, etc. It is quite common in daylight designs that the designer is not given the full details of the building that is under construction. In such situations the designer should make sensible assumptions as what the missing information may be

3.4 Method

The annual time-series of hourly values (i.e. 8,760) for diffuse horizontal illuminance are extracted from the climate file. The 4,380 highest values of diffuse horizontal illuminance for the condition sun altitude $\geq 0^\circ$ are retained and the rest discarded. The median value for the retained diffuse horizontal illuminance data is then easily determined using, say, a spreadsheet tool. For example, the median diffuse horizontal illuminance value determined from a standard climate file for Ostersund (Sweden) is 11,628 lux, Figure 3. In other words, this diffuse horizontal illuminance is attained for half of the year (when the sun is above the horizon). The daylight factor method assumes a constant ratio between internal and external illuminance. Applying the method here shows that, for Ostersund, the 'target' daylight factor (i.e. that needed to achieve 300 lux) is:

$$\frac{300 \times 100}{11,628} = 2.58\% \qquad (3)$$

In other words, for an internal illuminance of 300 lux to be achieved for half of the daylit year, the daylight factor must equal or exceed 2.58%. Thus, to achieve the design goal, half of the sensor points in the space should have a daylight factor that equals of exceeds 2.58%.

Using the same approach, the 'target' DFs for 32 European capital cities and Moscow are shown in Table 2. Note, the required value for Ostersund (2.58%) is slightly higher than that for the Swedish capital Stockholm (2.48%) because of the difference in prevailing diffuse illuminance availability between the two locations.

3.5 A transition 'roadmap'

The proposal described above is not for a full-blown climate-based solution – direct and indirect sun are not accounted for. However, unlike the 'clear sky' measures mentioned in this article, the cumulative illuminance approach has a defensible rationale. Furthermore, by shifting the analysis to measures of absolute illuminance, it prepares the ground for a relatively smooth transition to eventual, full-blown CBDM evaluations. For this transition to be effected, it would be necessary to assure potential developers of CBDM software that there will be a market for their tools. One could envisage, say, a three year 'overlap' period in standards/guidelines during which either the cumulative illuminance approach or

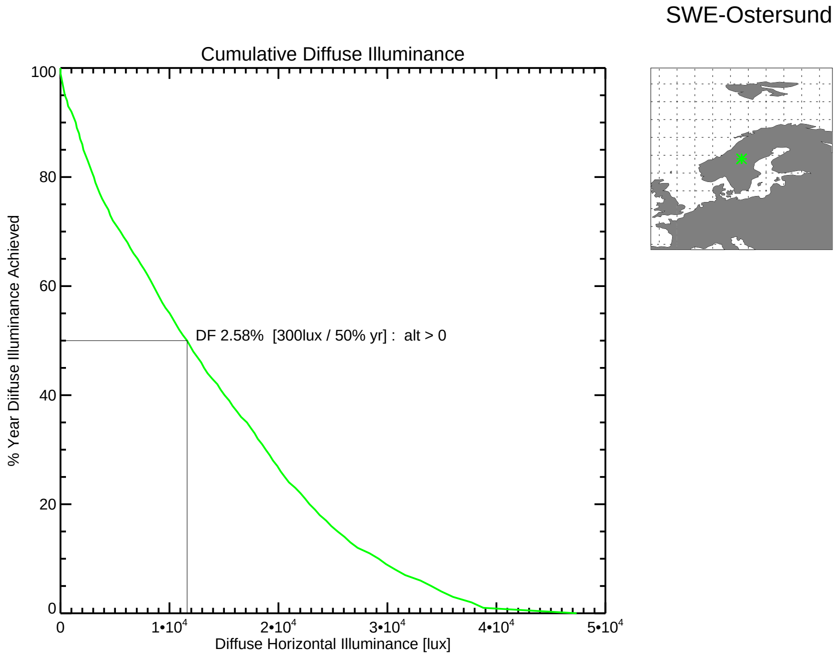

Figure 3: Cumulative diffuse curve for Ostersund, Sweden

CBDM could be used to demonstrate compliance – with perhaps a weighting in the credits to encourage CBDM. And then, at the end of that period, only evaluations founded on CBDM would be permitted. Such a provision would encourage software houses to invest the time and resources to develop end-user CBDM tools in the certainty of a guaranteed market for the product by a due date – thus solving the 'chicken and egg' conundrum noted earlier. Note that, although similar, or even identical, targets would be used with either approach, with CBDM it would be necessary to model user deployment of blinds etc. since direct (and indirect) sunlight now figures in the evaluation. It remains to be seen how the newly-introduced CBDM metrics fare in the US, though it seems likely that the development will add to the pressure here to progress in a similar direction. That already seems to have occurred with the introduction of the 'Baseline Schools Design' document which recommends evaluating daylight provision in terms of the Useful Daylight Illuminance scheme [18].

4 Discussion

Both the basis for daylight evaluation and the role that it plays in the building design process are at a crossroads. The increasing importance that daylight has in the performance evaluation of buildings for compliance purposes should lead to a renaissance in the field of applied daylighting. However, the standard evaluation techniques, on which nearly all compliance indicators are founded, are increasingly recognised as not fit-for-purpose and in need of upgrading. Furthermore, there has been no convincing demonstration that the standard methods are capable of advancement by incremental means, e.g. the various 'clear sky options'.

A long overlooked method offers an effective means to transition from a climate-insensitive performance measure (e.g. average 2% daylight factor) to one that is founded on the prevailing level of (diffuse) illuminance for the specific locale. Once made, this would offer secure 'footing' to assist the transition to full-blown climate-based daylighting metrics at some later date. The proposed cumulative diffuse illuminance method requires only modest enhancement of existing daylight factor prediction tools, and yet offers much needed 'connectivity' between a measure of daylight provision and the prevailing climate.

This article is the second of a series in support of the activities of CEN TC 169/WG11 – the first "Rethinking Daylighting and Compliance" was presented at the SLL/CIBSE 2013 International Lighting Conference in Dublin, Ireland [14]. It should be noted that the views expressed in this paper are those of the authors Mardaljevic and Christoffersen alone.

Table 2: Median diffuse illuminance and 'target' daylight factor for 33 capital cities

Country	Capital	Median diffuse illuminance [lux]	Median daylight factor [%]
Cyprus	Nicosia	18100	1.66
Malta	Valletta	16500	1.82
Greece	Athen	19400	1.55
Portugal	Lisboa	18220	1.65
Turkey	Ankara	19000	1.58
Spain	Madrid	16900	1.78
Italy	Roma	19200	1.56
Bulgaria	Sofia	18700	1.60
Romania	Bucharest	18200	1.65
Croatia	Zagreb	17000	1.76
Slovenia	Ljubljana	17000	1.76
Switzerland	Bern	16000	1.88
Hungary	Budapest	18100	1.66
Austria	Wien	16000	1.88
Slovakia	Bratislava	16300	1.84
France	Paris	15900	1.89
Luxembourg	Luxembourg	16000	1.88
Czech Republic	Prague	14900	2.01
Belgium	Brussel	15000	2.00
United Kingdom	London	14100	2.13
Poland	Warsawa	14700	2.04
The Netherlands	Amsterdam	14400	2.08
Germany	Berlin	13900	2.16
Ireland	Dublin	14900	2.01
Lithuania	Vilnius	15300	1.96
Denmark	Copenhagen	14200	2.11
Russian Federation	Moscow	14800	2.03
Latvia	Riga	13600	2.21
Estonia	Tallinn	13600	2.21
Sweden	Stockholm	12100	2.48
Norway	Oslo	12400	2.42
Finland	Helsinki	13500	2.22
Iceland	Reykjavik	11500	2.61

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