Conclusion to Reportership R3-26

Climate-Based Daylight Analysis

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1 Introduction

The recent history of daylight evaluation has been one of diminishing areas of application, and, in the eyes of design team colleagues, diminished relevance. A daylight factor evaluation was often undertaken as an afterthought, and rarely did the findings have a substantive impact on the design. Similarly, from certain perspectives it seemed that fundamental areas of daylighting research were in the doldrums - continued reliance on the half-century old daylight factor had, inevitably, led to a sense of stagnation in sectors of the research community.

Two seemingly concurrent, but out-of-step and totally independent developments are changing both the perceived importance and the nature of daylight evaluations. The first is the increasing demand to demonstrate compliance at the design stage with recommended measures of building performance, e.g. the LEED rating system. The need for this appears to be widely accepted throughout the developed world, and the rate of uptake by practitioners is ever increasing in response to pressure and encouragement from governments, regulatory bodies, etc. For those striving to effect good daylighting design however, the race for compliance is by no means entirely good news because the recommendations are founded on schema that ignore fundamental parameters such as building orientation and prevailing climate. The second development is a major advancement in the way that daylight evaluations are carried out. This advancement, called climate-based daylight modelling, can address the very real concerns that practitioners and researchers are now voicing regarding the high potential for 'compliance chasing' resulting in poor design choices for buildings.

This report contains: a brief overview of the history and practice of daylight evaluation as it is commonly carried out; a description of the new climate-based schema for daylight modelling; a list of activities related to the Reportership; and, a discussion of issues arising. It concludes with a recommendation to continue these developments under the aegis of a full CIE Technical Committee on climate-based daylight modelling.

1.1 Background

Design guidelines worldwide recommend daylight provision in terms of the long-established daylight factor (DF). Formulated in the UK over fifty years ago, the daylight factor is simply the ratio of internal illuminance to unobstructed horizontal illuminance under standard CIE overcast sky conditions [1]. It is usually expressed as a percentage, so there is no consideration of absolute values. The luminance of the CIE standard overcast sky is rotationally symmetrical about the vertical axis, i.e. about the zenith. And, of course, there is 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). In other words, the predicted DF value would be the same if the building had North-facing glazing in Stornoway or South-facing glazing in Brighton. The same would be true if the locations were Moscow and Miami - or indeed for any city in any country.

The daylight factor was, until recently, the sole quantitative ‘measure’ of daylight in buildings. The word measure needs to be treated with some caution since the daylight factor is not a direct indicator of actually occurring daylight provision - although it is often taken to be so. The daylight factor is precisely what it was defined to be: a ratio of illuminances under a specific sky condition. The daylight factor is therefore a proxy for actual daylighting. It is not at all clear however just how effective a proxy the daylight factor actually is. In fact, the question has rarely been posed. Aside from a small number of exceptions [2, 3], the effectiveness of the daylight factor as a ‘measure’ of daylight has been largely accepted by practitioners and researchers alike. The daylight factor continues to be employed routinely and, for most part, uncritically.

Daylight designers commonly make use of the daylight factor, which nowadays can be determined with relative ease by non-experts. The real value of the designer’s expertise however is in envisioning those many aspects of daylight provision that are *not* accounted for by the daylight factor. These aspects are many and varied. Key amongst them, however, are the contribution of the sun to the overall illumination of the building and the potential for glare resulting from direct sun and/or skylight. The first of these - the illumination contribution of the sun - can only be very approximately estimated. In truth, it is a qualitative judgement founded on experience and intuition rather than numerous computations of light transfer. The second depends in part on a consideration of geometrical relations between the progression of the sun and the configuration of the building, i.e. the windows of the building, their orientation and any nearby obstructions. This involves envisioning the progression of the sun illuminated surfaces inside the building, and estimating the potential for views of bright sky that might be a cause for glare. In other words, for either case there is an envisioning of sorts by the designer of the spatio-temporal dynamics of daylight illumination. These evaluations can be informed to a limited degree by shadow pattern studies of solar penetration. In addition, of course, an experienced designer will offer advice on a great many other, secondary aspects of daylighting design for the building. However valuable the advice offered by the daylight designer, it is unlikely that it could be distilled into a codified scheme and, ultimately, some numerical measure of predicted performance.

The drive towards sustainable, low-energy buildings places increasing emphasis on detailed performance evaluation at the early design stage. The role that daylight evaluation plays in the design process has acquired a new impetus as the need to demonstrate compliance with various ‘performance indicators’ becomes ever more pressing. Practitioners have become increasingly vociferous in their criticism of the standard method for daylight evaluation [4]. Of particular concern is the lack of “realism” of the daylight factor approach and its fundamental inability to be part of an “holistic” solution that offered reliable, quantitative measures of actual daylight and which also informed on the effectiveness or otherwise of solar shading strategies, since the two are inextricably related.

The situation with regard to the confusion and uncertainty that practitioners experience when attempting to effect “good daylighting design” cannot be overstated. Practitioners encounter guidelines and recommendations for target daylight factors values that, from their experience, they know are likely to result in over-glazed buildings with excessive solar gain. Furthermore, the hoped for daylight benefit (i.e. the displacement of electric lighting usage) is often not achieved because, in over-glazed buildings, the blinds/shades are likely to remain drawn much of the time and the electric lights switched on. Note that ‘practitioner’ has been used rather than ‘daylight designer’. The skills of the experienced daylight designer are not in question, and the majority of building projects would doubtless benefit from their expertise. As noted however, the daylight designer’s input is unlikely to lend itself to ready quantification for the purpose of demonstrating compliance at the design stage.

1.2 Climate-based daylight modelling

Climate-based daylight modelling (CBDM) is the prediction of various radiant or luminous quantities (e.g. irradiance, illuminance, radiance and luminance) using sun and sky conditions that are derived from standard meteorological datasets. Climate-based modelling delivers predictions of absolute quantities (e.g. illuminance) that are dependent both on the locale (i.e. geographically-specific climate data is used) and the building orientation (i.e. the illumination effect of the sun and non-overcast sky conditions are included), in addition to the building’s composition and configuration.

The term climate-based daylight modelling does not yet have a formally accepted definition - it was first coined by Mardaljevic in the title of a paper given at the 2006 CIBSE National Conference [5]. However it is generally taken to mean any evaluation that is founded on the totality (i.e. sun and sky components) of contiguous daylight data appropriate to the locale for a period of a full year. In practice, this means sun and sky parameters found in, or derived from, the standard meteorological data files which contain hourly values for a full year. Given the self-evident nature of the seasonal pattern in daylight availability, an evaluation period of a full year is needed to fully capture all of the naturally occurring variation in conditions that is represented in the climate dataset. The exact pattern of hourly values in a standard climate dataset is unique and, because of the random nature of weather, it will never be repeated in precisely that way. Climate datasets are however representative of the prevailing conditions measured at the site, and they do exhibit much of the full range in variation that typically occurs. There are a number of possible ways to use climate-based daylight modelling [4, 6, 7, 8, 9]. The two principal analysis methods are cumulative and time-series.

A cumulative analysis is the prediction of some aggregate measure of daylight (e.g. total annual illuminance) founded on the cumulative luminance (or radiance) effect of (hourly) sky and the sun conditions derived from the climate datset. It is usually determined over a period of a full year, or on a seasonal or monthly basis, i.e. predicting a cumulative measure for each season or month in turn. Evaluating cumulative measures for periods shorter than one month is not recommended since the output will tend to be more revealing of the unique pattern in the climate dataset than of "typical" conditions for that period. The cumulative method can be used for predicting the micro-climate and solar access in urban environments, the long-term exposure of art works to daylight, and the determination of seasonal dynamics of daylight and/or shading at the early design stage.

Time-series analysis involves predicting instantaneous measures (e.g. illuminance) based on all the hourly (or sub-hourly) values in the annual climate dataset. These predictions are used to evaluate, for example, the overall daylighting potential of the building, the occurrence of excessive illuminances or luminances, as inputs to behavioural models for light switching and/or blinds usage, and in assessing the performance of daylight responsive lighting controls.

Evaluations founded on the cumulative approach have the potential to influence the design of the building form at the very earliest stages of conception. For example, massing studies could be evaluated in terms of their interaction with the local solar micro-climate. Fundamental decisions about the building shape would be informed by an appreciation of how the form and existing context determine the magnitude and quality (i.e. direct and diffuse proportions) of the incident daylight radiation. As the design evolves, cumulative monthly analyses could be used to disclose the prevailing levels and seasonal dynamics of daylight exposure, for both the external envelope and roughly-modelled internal spaces. The cumulative approach therefore has the potential to become a valuable tool to help guide the design of the building from the initial conception onwards. It is unlikely however to serve as the basis for a daylight metric since this would need to be founded on the likely range and degree of occurrence of instantaneous illuminances, which cannot be reliably inferred from a cumulative measure of illumination. Thus a daylight metric would needed to be based on a time-series of instantaneously occurring daylight illuminances. As noted, evaluations should be for an entire year, however only data for the occupied periods (e.g. the working day) needs to be considered.

2 Activities related to the Reportership

The activities related to this Reportership have been both academic and professional in nature. For either case, the activities pertain the theoretical basis, refinement, application and wider-promotion of climate-based daylight modelling amongst researchers and practitioners alike. The academic-related activities have included the following:

- Publication of articles in peer-reviewed journals.
- Presentation of papers at conferences.

- Teaching of the science and application of climate-based daylighting modelling at the Masters level.
- Participation in relevant working groups.
- Open and free exchange of information etc. with other researchers.

Whereas the professional-related activities have been:

- Application of CBDM to consultancy projects.
- Revision of British Standard 8206-2 (Daylight in Buildings).
- Planning and urban deisgn.

The categories are not strictly separate because, at this early stage of development for climate-based modelling, the application examples often contain sufficient original research to warrant publication. Brief details related to the activity in each of the categories are outlined below.

2.1 Publications and presentations

These include papers on supporting techniques and core methodology [10, 11], daylight metrics [8, 9], conferences such as the Teaching in Architecture 2007 at Krems [12] and the VELUX Daylight Symposium in Bilbao [13]. Additionally, there have been papers and presentations on case-study applications of climate-based daylight modelling to 'live' building projects [5, 14, 15].

2.2 Teaching

The background and methodology for CBDM forms a core part of the 'Climate and Daylight' module of the 'Energy and Sustainable Building Design' (ESBD) masters course run by the IESD.[1] The ESBD masters teaches the basics of daylight, thermal and air-flow simulation within the general context of low-energy building design. Necessarily, the "hands-on" daylight simulation teaches application of the standard method (i.e. daylight factors) as is commonly used in practice. However this is supplemented with lecture notes derived from research publications on CBDM, which also serve as a critique of the standard method. Students have remarked that, knowing something of climate-based modelling, they actually feel better prepared to make use of the standard daylight factor method since they now have a good understanding of its fundamental limitations. The course is perhaps unique in offering the very latest research findings as a core part of the syllabus material.

More generally, an understanding of daylight informed from climate-based approaches is radically different from that offered by the traditional modes of evaluation where the 'mind-set' is that of static/snapshot illumination scenarios. Architectural students have noted that it is *easier* to understand

[1] http://www.iesd.dmu.ac.uk/msc/esbd_details.htm

daylighting through climate-based principles than it is from trying to unpick the significance of a combined daylight factor and shadow pattern study. Thus, CBDM has the potential to lead to fundamental changes in the teaching of daylighting principles in schools of architecture etc.

2.3 Working groups and information exchange

Climate-based daylight modelling has been the focus of a number of CIBSE Daylight Group (DG) events from 2006 onwards. The potential role of CBDM in urban planning engendered quite a heated debate in a 2006 meeting on 'rights to light' - a century-old arcane methodology that is still used to determine measures of 'daylight injury'. Other DG meetings have included sessions dedicated to predicting the performance of the light-redirecting material Serraglaze (2007), and open forum meetings on daylight metrics.

Mardaljevic has participated in exchanges with the US Daylighting Forum, e.g. by telephone conference and e-mail, and in face-to-face meetings at conferences. In particular, there have been regular exchanges with Lisa Heschong regarding the Heschong-Mahone Group project on daylight metrics.

2.4 Application to consultancy projects

Climate-based daylight modelling has been applied to a number of consultancy projects. Perhaps more than any other activity, these evaluations have generated practitioner interest in CBDM. It is known that Arup Engineering have sufficient in-house capabilities to carry out CBDM themselves, and have done so on a number of projects.[2] The details of these however are not in the public domain.

For the projects carried out by Mardaljevic, he has generally managed to obtain permission from the clients to publish the findings. What is striking about these projects is the range of application, e.g. daylight injury for the New York Art Students League building, combined daylight provision and visual comfort for the New York Times Headquarters Building, performance evaluation of light redirecting glazing, a parametric study of daylight provision for buildings with skylights. What these projects have revealed is that the domain of application is far larger than, say, the case of a typical side-lit office space. This in turn presents issues for consideration in the design of an end-user system since these invariably must offer restricted functionality if they are to be 'easy' to use.

2.5 Revision of British Standard 8206-2

British Standard 8206-2 'Lighting for Buildings Part 2: Code of Practice for Daylighting' has just undergone revision (Summer 2008). The last revision prior to the this was in 1992. The current revision was carried out between

[2] Private communication: Bob Venning, Arup, UK.

December 2006 and May 2008, with the final version ready for review in August 2008. The review panel comprised: Chair Mr Peter Raynham (UCL), Dr Paul Littlefair (BRE), Dr Arfon Davies (Arup), Dr Kevin Mansfield (UCL) and Dr John Mardaljevic (DMU).

Mardaljevic was invited to join the panel specifically to address the issue of including metrics founded on climate-based measures of daylight in the revision. It was established in the first few meetings that, to date, there had been insufficient groundwork on climate-based metrics, and that significant research remains to be done before authoritative metrics could be recommended in a British Standard. Despite this, the panel voted to include a technical annex on climate-based daylight modelling to serve as notice that a more substantive future revision of the standard is expected to recommend measures founded on climate-based metrics. This is perhaps the most significant endorsement to date of climate-based daylight modelling by a government or regulatory body.

2.6 Planning and urban deisgn

Solar access and the solar micro-climate have long been a consideration in urban planning, even if their precise definitions are somewhat vague. CBDM offers the means to provide definitive measures of the urban solar micro-climate. For example, one measure of the solar micro-climate could be rigorously specified as the total annual irradiation (or illumination), i.e. the total energy (or the visible part) from the sun and the sky incident on building facades, arriving directly and from reflections [16, 17, 18, 19]. This quantity has a direct bearing on the delivered power from, say, a building integrated photovoltaic (BPIV) array. Thus it could be used to determine measures of injury when a proposed building overshadows a BIPV array. Issues such as these will come to the fore as solar-dependant technologies become more common in urban settings. Investors in these technologies will need assurance that there are reliable procedures in place to determine a just measure of financial compensation should the performance of a BIPV array be degraded by later building developments.

It should be noted that the current guidelines used in so-called 'Rights to Light' disputes are based on a century-old paradigm that is woefully inadequate for the purpose of assessing impact to energy generating system. The New York Art Students Leaguex (ASL) study (carried out by Mardaljevic in 2005) appears to be the first - and possibly only - solar access dispute where the legally-binding settlement was decided on climate-based metrics. Surveyors - a notoriously conservative industry sector - have been made aware of the ASL study at special CIBSE Daylight Group events dedicated to 'Rights to Light' issues. To say that it provoked interest and consternation (rather more of the latter) is putting it mildly. Progress here will require a technical-legal approach, i.e. collaboration with experts in construction and planning law.

3 Issues arising

3.1 Basic research

As noted in earlier sections, there are a number of areas where further research in climate-based daylight modelling is needed. The computational mechanics of climate-based daylight modelling are reasonably well advanced. Though it should be noted that the existing implementations are mostly based on the *Radiance* system [20]. These software range from purely in-house research tools (e.g. XDAPS [21]) to end-user versions such as DAYSIM from the NRC, Canada[3]. It is fair to note that all implementations, including the 'end-user' DAYSIM system, require operation by a user that is at least competent if not expert with the *Radiance* system. Additionally, the user should be reasonably familiar with the science of climate measurement (at least the radiant energy part), and also the handling/manipulation of climate data. Thus climate-based daylight prediction is still very much the preserve of a small handful of experts, though the numbers are steadily growing.

Following on from the mechanics of computation are the issues relating to data input requirements, and in particular the use of sky models to generate the sky luminance distributions from the basic quantities in the climate files. There is as yet no consensus on the selection of sky model types or the use of sky model blends for climate-based simulation. This was the case when the number of commonly used sky model types was just a handful, i.e. far fewer than the fifteen types offered by the CIE General Sky [22]. The large number of types offered by the CIE General Sky certainly does not simplify the matter of selection. However, a recent study by Tregenza suggests that a subset of the fifteen types will most likely suffice for most climates [23]. That study examined the probability of occurrence of the various sky types using data collected at the BRE. Tregenza found that:

> *five sky types account for nearly 80% of the scanned data sets; some types are rarely applicable or not used at all. This suggests that the daylight climate could be characterized by a small subset of standard types without significant loss of accuracy.*

What is not yet clear however is how to select the most suitable sky type and/or blend on a time-step basis from the data contained in climate files. A recent paper by Dumortier and Kobav gives the first results for a possible solution in which the Perez All-Weather model is used as means to select suitable types from the CIE General Sky [24]. It is however early days and further work along these lines is needed.

Climate-based daylight evaluations can generate huge amounts of time-varying illuminance data that needs to be processed, reduced and interpreted[4]. Whilst a summary metric might be the end goal, the spatio-temporal dynamics of daylight illumination contains much that can inform the designer

[3] http://irc.nrc-cnrc.gc.ca/ie/lighting/daylight/daysim_e.html

[4] For example, a recent parametric study on daylight provision for the VELUX corporation by Mardaljevic generated over 140Gb of illuminance data [15]

about the prevailing character of daylight illumination in the space. Processing these data into forms that can readily convey the significance of the patterns and rhythms of the daylight in the space is a challenging task in itself [25, 26]. The Lightsolve project at MIT has as one of its goals the formulation of suitable graphics for end-users to easily interpret the output from climate-based simulations [27, 28].

It is the formulation of daylight metrics however which probably requires the greatest sustained research effort. The Heschong-Mahone Group (CA, USA) are currently engaged in a project to determine daylight metrics.[5] The results of that study are eagerly awaited by those in the daylight community with an interest in climate-based daylight modelling. Regardless of the success of the Heschong-Mahone Group (H-MG) project, it is almost certainly the case that one project is unlikely to answer all the questions and issues related centrally and peripherally to the formulation of definitive climate-based daylight metrics. Recall that dynamic thermal modelling today is the accumulation of numerous research projects across the developed world over the last three decades. The H-MG project should therefore be seen as a 'pioneer' effort, hopefully the first of several. One of the candidate metrics under consideration in the H-MG project is the Useful Daylight Illuminance scheme [5, 8, 15].

3.2 Industry sector

The demand for climate-based modelling by practitioners is certainly growing, though it is impossible to estimate the number of projects carried out since the majority are not generally reported. Various high-profile projects that have received publication have been instrumental in engendering interest in the new approaches, and anecdotal evidence from software developers indicates a steady increase in the number of enquiries regarding climate-based modelling.[6]

As note earlier, the key factor limiting wider uptake of climate-based modelling is the lack of authoritative climate-based metrics. Another significant factor is the lack of best-practice guide(s) to carrying out climate-based daylight modelling, i.e. something comparable to what has appeared in various manuals and technical memoranda for thermal and airflow modelling (e.g. CIBSE guides or their equivalents in other countries). Whilst the work required to compile the necessary guides will probably not have the cachet of that needed to formulate the daylight metrics, it is nonetheless a vital part of demonstrating quality assurance in the process and should not be overlooked.

In addition to designers and architects, the manufacturers and vendors of daylighting and daylight responsive systems have much to gain from the formulation of climate-based daylight metrics. These systems include: innovative glazing materials (e.g. Serraglaze); light-pipes; daylight responsive

[5] http://www.h-m-g.com/DaylightPlus/Daylight_Metrics.htm

[6] Private communication: Craig Wheatley, Technical Manager, Integrated Environmental Solutions, Glasgow, UK.

lighting controls; brise soleil and shading devices etc. Marketing of innovative daylighting systems has always proven to be difficult because the currently-accepted "measure" of daylighting performance (i.e. the daylight factor) gives no indication of how much natural light and how often. Data on the magnitude and occurrence of absolute measures of natural illumination - precisely how much and how often - are vital to reliably assess both the performance-effectiveness and the cost-effectiveness of daylighting systems. Thus the hoped-for emergence of climate-based daylight metrics will greatly assist in the general promotion and marketing of daylighting and daylight responsive systems. The climate-based study on skylights in residential buildings was immediately made public by VELUX on their Daylight website.[7] Whilst it hardly bears remarking that the addition of skylights will increase the daylight provision in a space, the degree to which this occurs can only be reliably quantified using climate-based modelling. In principle, VELUX could use these findings as a basis for improved marketing of their skylight products.

3.3 Daylighting guidelines

As noted in the Introduction, there is an increasing emphasis on demonstrating compliance with guidelines and recommendations at the design stage. Thus building designers are resorting more and more to simulation as means of demonstrating compliance with schemes such as LEED:

> *The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), provides a suite of standards for environmentally sustainable construction. Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in 50 US States and 30 countries covering 1.062 billion square feet (99 km^2) of development area.*[8]

Daylight is one of the considerations in the determination of a LEED credit rating. In version 2.1 the requirement for the LEED daylight credit (8.1) was phrased as follows: "Achieve a minimum Daylight Factor of 2% (excluding all direct sunlight penetration) in 75% of all space occupied for critical visual tasks.[9] The note in parentheses that all direct sunlight penetration should be excluded is somewhat vague since LEED recommends a standard daylight factor calculation which, of course, makes no account of sunlight, direct or otherwise. In version 2.2 the metric was changed to "glazing factor", where the goal is to "achieve a minimum glazing factor of 2% in a minimum of 75% of all regularly occupied areas".[10] In either version, the metric is climate and orientation *insensitive*. Thus, the outcome of the evaluation would be the same if the building had North-facing glazing and was intended for Seattle,

[7] http://www.thedaylightsite.com/showarticle.asp?id=166&tp=6
[8] From the Wiki page on LEED.
[9] http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf
[10] http://www.usgbc.org/ShowFile.aspx?DocumentID=1095

or South-facing and intended for Texas. To the onlooker uninitiated in the habits and beliefs of the traditional daylight practitioner, the notion that a climate-insensitive parameter could play any role in determining either the form of a building or the construction of its facade must seem very strange indeed. Particularly so when this parameter is applied uniformly across a continent that experiences such extremes in prevailing climatic conditions.

Seemingly in an attempt to address the idealised nature of the basis of daylight evaluation in LEED version 2.2 has a second option where, 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.*

Whilst this may appear, at first, reasonable, the LEED documentation gives 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, 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. 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 value (i.e. diffuse horizontal). Whatever the shortcomings of the daylight factor and glazing factor methods - they are many and manifest - at least those methodologies are self-consistent rather than arbitrary. With the Clear Sky option, major decisions about the building envelope could be made on the basis of meaningless data.

The purpose of the above is not just to bring to attention an unsound methodology, which somehow appeared in a key guidance document. Instead, a deeper concern is with state of grassroots knowledge about daylighting in the practitioner, and indeed 'daylight specialist' community. It should be noted that, at the time of writing this report, there appears to be no material anywhere on-line that is querying or challenging the formulation of the LEED

Clear Sky option. This is evidently an unsatisfactory state of affairs, and one hopes that it will be remedied in Version 3.

4 Conclusion and recommendations

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 - the LEED Clear Sky option is testament to the failure of attempting to repackage the daylight factor method for non-overcast skies.

Climate-based daylight modelling is now gaining acceptance as the most promising, perhaps even the only, line of research that will deliver truly effective tools for the realistic evaluation of daylight in buildings. The number of active researchers is small but steadily growing, and the potential to deliver major changes in the practice of daylight evaluation is great. Thus, at this crucial juncture, it is important that the efforts of the research community are well co-ordinated, and that decisions which could have far-reaching consequences are made under conditions of the greatest transparency and fullest-possible peer review. To this end, the creation of CIE Technical Committee (Division 3) on Climate-Based Daylight Modelling is proposed. The issues to be addressed by the TC over an anticipated four year duration would include - but are not restricted to - the following:

- To describe the state-of-the-art in CBDM and determine levels of research activity.
- To identify themes in ongoing areas of CBDM research and forecasting of future developments.
- To identify key areas of core or supporting research which are either lacking or with insufficient activity.
- To determine key application areas for CBDM and the required data pre-requisites.
- To codify an authoritative workflow for CBDM that is compliant with agreed quality assurance criteria.
- To provide guidance on the application of CBDM to predict emerging daylight metrics.

Interim and final reports would be prepared as required to document the activities, findings, conclusions and recommendations of the TC. The Technical Committee, if approved, should include the majority of key researchers in the field, and have a wide representation across member countries.[11]

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