Daylighting Monitoring Protocols & Procedures for Buildings

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A report of Task 21 / Annex 29
Daylight in Buildings
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Solar Heating & Cooling Programme

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by

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with the contribution of Subtask D participants

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SUMMARY

The lack of daylighting monitoring protocols and procedures for buildings has greatly contributed to the small number of monitored daylit buildings. As a result, high electricity savings claims from daylighting were mostly driven from modeling, illuminance measurements from test cells or scale modeling, or from just high daylighting availability. Daylighting field-measured data with respect to transient daylighting contribution and electrical lighting control are very limited. Furthermore, well-daylit buildings do not necessarily ensure energy savings as occupancy patterns, improper daylight-linked electrical lighting design, and associated thermal loads can negate high potential energy savings. For daylighting to be considered as a source of energy savings in buildings, monitoring the daylighting performance of real case studies becomes an essential procedure. The objectives of the monitoring are:

This paper presents protocols and procedures to monitor the daylighting performance of buildings. The daylighting performance addressed in this document includes daylighting contribution to indoor lighting; energy savings from displaced electrical lighting consumption; and associated thermal loads from daylighting. This paper also presents procedures that would explain a superior/poor daylighting performance, thus, identifying potential retrofitting measures. The goal is to provide the building-related industry and institutions with a method to monitor the daylighting performance of buildings, and to compare the daylighting performance of several buildings. Building occupants' appraisal towards daylighting is addressed in another document. Daylighting monitoring protocols and procedures are necessary to improve our understanding of daylighting as a source of energy savings.

This document accommodates three levels of monitoring assessment: measured performance, predicted performance, and monitoring of performance control parameters. The outputs of each level are presented. They relate to lighting consumption and savings; contribution to illuminance; and associated thermal loads. The document also suggests the monitoring of daylighting hardware and occupancy aspects to help explain a superior/poor performance. Monitoring procedures such as test-point and daylit zone selection and illuminance recording are presented. Finally, the document outlines a step-by-step method to implement the protocols.

This official IEA report is a deliverable of IEA SHC Task 21/ IEA BCS Annex 29: Daylight in Buildings. The Task focuses on daylighting systems and strategies which can be applied in new and existing buildings with a high potential electricity saving potential such as offices, schools, commercial, and institutional buildings. The daylighting performance of these strategies and systems is tested in laboratory facilities, through modeling, and in real case study buildings. This paper provides methods and procedures to evaluate the daylighting performance of real buildings. This document was developed to monitor the daylighting performance of IEA SHC Task 21/ BCS Annex 29 case studies located in Europe, North America, and Australia. It is a deliverable of Subtask D research projects. The main objective of Subtask D, as stated in the Implementing Agreement of Task 21/Annex 29, is "to demonstrate the viability of daylighting buildings in various world climatic zones as a means of achieving significant improvements in building energy efficiency while maintaining a satisfactory visual and thermal environment for occupants."

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DAYLIGHTING MONITORING PROTOCOLS

AND PROCEDURES FOR BUILDINGS

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1. INTRODUCTION

This paper presents protocols and procedures to monitor the daylighting performance of buildings. This official IEA report is a deliverable of IEA SHC Task 21/ IEA BCS Annex 29: Daylight in Buildings. The Task focuses on daylighting systems and strategies which can be applied in new and existing buildings with a high potential electricity saving potential such as offices, schools, commercial, and institutional buildings. The daylighting performance of these strategies and systems is tested in laboratory facilities, through modeling, and in real case study buildings. This paper provides methods and procedures to evaluate the daylighting performance of real buildings.

The daylighting performance addressed in this document includes daylighting contribution to indoor lighting; energy savings from displaced electrical lighting consumption; and associated thermal loads from daylighting. This paper presents procedures and methods that would explain a superior/poor daylighting performance, thus, identifying potential improvement measures. The goal is to provide the building-related industry and institutions with a method to monitor the daylighting performance of buildings, and to compare the daylighting performance of several buildings. Building occupants' appraisal towards daylighting is addressed in another document (Hygge and Lofberg 1997).

Daylighting monitoring protocols and procedures are necessary to improve our understanding of daylighting as a source of energy savings. Research shows that energy savings from daylighting have rarely been demonstrated in real buildings. In fact, a study conducted in 1985, shows that the performance data for daylighted buildings virtually does not exist (Usibelli et al. 1985; Atif 1994). Since then, very few daylighted buildings have been the subjects of performance assessment. As a result, our knowledge of daylighting as a source of energy savings in buildings is still very limited, as it lacks a critical performance evaluation of the daylighted buildings.

2. OVERVIEW OF SUBTASK D: DAYLIGHTING MONITORING OF CASE STUDIES

This document was developed to monitor the daylighting performance of IEA SHC Task 21/ BCS Annex 29 case studies located in Europe, North America, and Australia. It is a deliverable of Subtask D research projects. The main objective of Subtask D, as stated in the Implementing Agreement of Task 21/Annex 29, is "to demonstrate the viability of daylighting buildings in various world climatic zones as a means of achieving significant improvements in building energy efficiency while maintaining a satisfactory visual and thermal environment for occupants." The Annex identifies the scope of the Subtask as limited to the following measured data: "illumination, luminance distribution of interior space, electricity use for lighting, total building energy use, and user acceptance of environmental conditions."

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[3] Building Research Establishment, Indoor Environment, UK.

The Subtask includes the following activities:

1. Preparation of a documentation program and a database in which the case studies are described in a typological context as a basis for selection of case studies demonstrating integration of daylighting systems and control strategies in various climates.

2. Establishment of adequate monitoring procedures.

3. Development of procedures for the evaluation of user acceptance.

4. Monitoring of buildings and user acceptance studies in selected case studies.

5. Production of case study reports.

This document is a deliverable of activity no. 2 in the above list.

3. OBJECTIVES AND SCOPE

3.1. Problem and Rationale for Daylighting Monitoring

The need for monitoring the daylighting performance of real case studies is due to several factors, the most important of which are:

1. The number of monitored daylit buildings is very limited.

2. High electricity savings claims from daylighting were mostly driven from modeling, illuminance measurements from test cells or scale modeling, or from just high daylighting availability.

3. Data related to transient daylighting contribution and electrical lighting control response with real occupancy are very limited.

4. Well-daylit buildings do not necessarily ensure energy savings as occupancy patterns, improper daylight-linked electrical lighting design, and associated thermal loads can negate high potential energy savings.

3.2. Objectives of the Monitoring Protocols

For daylighting to be considered as a source of energy savings in buildings, monitoring the daylighting performance of real case studies becomes an essential procedure. The objectives of the monitoring are:

1. To assess the “real” and “ transient” daylighting performance of buildings.

2. To assess the potential of electrical lighting reduction from daylighting based on climate and building type.

3. To identify problems and solutions related to interactions with occupancy patterns and electrical lighting control systems that prevents daylighting from reaching expected savings.

4. To define overall energy savings associated with daylighting such as increase (or reduction) of thermal loads from lighting, and solar and conductive loads.

5. To ensure a useful daylighting performance comparison among the different Subtask case studies.

The protocols will ensure comprehensive and consistent data delivery to designers.

3.3. Scope and Limitations

Measuring daylight in real buildings is a difficult task. There is also a lack of consensus on some aspects of daylighting performance indicators. Furthermore, long-term monitoring can be very expensive, and sometimes impractical. The method presented in this document is based on the following assumptions:

1. The daylighting performance is limited to:

    daylighting contribution to illuminance
    reduction of electrical lighting consumption,
    reduction of thermal loads associated with daylighting, or contribution to heating needs.

2. The indoor illuminance is an easy parameter to measure, but it is not the only parameter to assess the daylighting performance in buildings. Post-occupancy evaluation and reported occupants' responses will act as support elements to assess occupant's satisfaction.

2. Subjective aspects toward daylighting design are addressed by an activity within IEA SHC Task 21, i.e., the post-occupancy evaluation (Hygge and Lofberg 1997).

3. Long-term monitoring of illuminance (and electrical lighting consumption) is very expensive.

4. Monitoring the daylighting performance of the entire buildings is very expensive if the building is large. A selected space assessment can be an alternate solution.

5. Inference from a short term monitoring to an annual performance is based on several assumptions of occupancy patterns and sky conditions.

6. Recording several test point illuminance measures is expensive and can be impractical. The daylighting contribution to indoor illuminance is limited to selected test measurements. The increase of the sample will increase the accuracy of the measures for daylighting contribution to indoor illuminance.

7. Daylighting is often associated with high thermal loads that should be accounted for in the overall energy savings scheme. An integrated daylighting, cooling, and heating design is essential for good passive solar and whole building performance.

8. Building use affects lighting requirements and occupancy patterns (e.g. schools, offices, factory, etc.). This protocol should be adapted to each building use.

4. PERFORMANCE INDICATORS

The outputs of the monitoring are presented in the following sections. However, two essential levels of performance indicators used in this monitoring are :

1. The fraction of annual (or short term) lighting electricity use per unit of floor area displaced by daylighting.

2. The fraction of annual (or short term) illumination requirements provided by daylighting (or the percent of daylight levels-hours when the indoor illuminance is higher than a target illuminance)

The basecase for the daylighting performance is the absolute annual (or short term) lighting electricity use per unit of floor area for the same building (or space) with no daylighting contribution.

5. LEVELS OF MONITORING/ASSESSMENT

There are three suggested levels of monitoring/assessment:

1. Measured performance.
2. Measurements of performance control parameters.
3. Predicted annual performance based on short-term measurements.

Measured performance provides a detailed hard-fact data on the daylighting performance over a short-term period. The monitoring of performance control parameters such as occupancy, lighting controls systems, and glazing transmittance, will help explain the superior or poor daylighting performance. The predicted performance is important to reflect the annual performance that cannot otherwise be achieved with short-term monitoring. Figure 1 shows a schematic description of these assessment levels.

5.1. Measured Performance Level (Selected Space)

The measured daylighting performance is over a short-term period in a selected space (s) of the case study. Measured parameters should reflect the daylighting contribution to indoor illuminance and the electrical lighting displaced by daylighting. Figure 2 shows a schematic description of the measured performance level.

Monitoring will include:

1. One-week measurement of horizontal illuminance in the selected space for typical summer, winter, and fall/spring seasons (around June 21, Dec. 21, and Sept./Mar. 21). Monitoring should include at least summer and winter seasons. An additional day should include measurements for overcast sky conditions, for the calculation of the Daylight Factor at the selected daylit zones. Vertical illuminance should be measured in buildings such as museums, classrooms, Display rooms, etc.

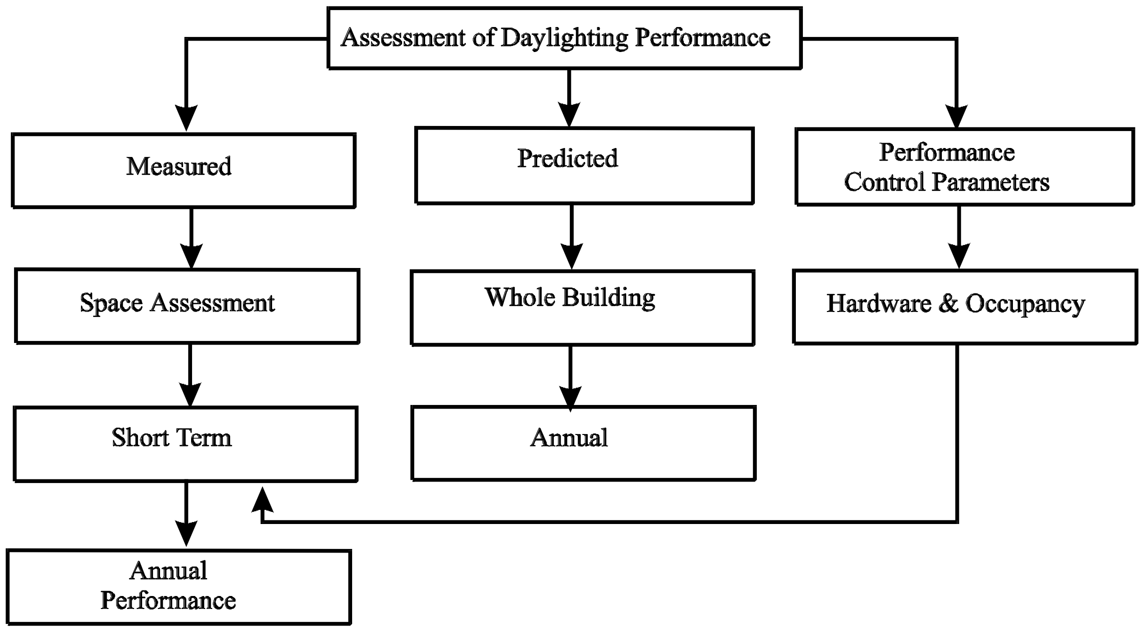

Figure 1. Schematic description of the daylighting performance assessment methods

If the measurements are made with the lighting off, then the electrical consumption will be unusual that week. Illuminance should be measured during nighttime with electrical lighting on and subtracted from the illuminance measured during daytime (if the lights were on). In the case of continuous dimming systems, illuminance levels should be measured during nighttime under different power levels and subtracted from the daytime measurements (with corresponding power levels). Another extreme alternative is that the electrical consumption data should surround but not include the illuminance measurement week.

2. One-week measurement of external horizontal illuminance. It should be simultaneously recorded with the indoor illuminance measurements. It has also to be measured to reflect the availability of daylight just before daylight enters the building.

3. One-month monitoring of the electrical lighting consumption in the space for typical summer and winter seasons. This month should include the week of illuminance measurements. Direct extrapolation or estimation of annual lighting consumption would be made based on these measurements.

4. Measured or calculated lighting consumption with all lights on, or at full power consumption in case of continuous dimming. This can be estimated from the design lighting power density (and power factor), or can be measured. This would be the basecase for energy saving calculations for the selected space(s).

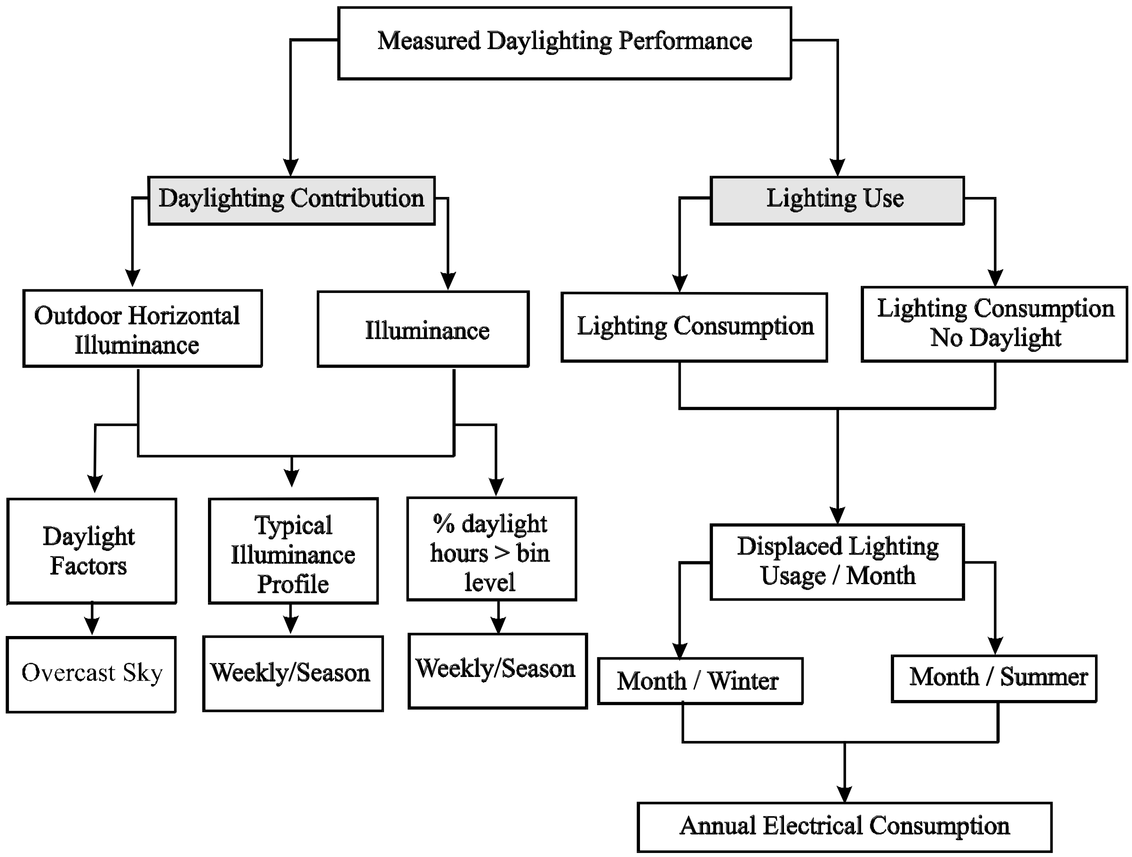

Fig. 2. Schematic description of the daylighting monitoring process

5.1.1 Output of the Measured Performance Level

Expected outputs and performance indicators of the measured performance level are:

Lighting consumption and savings

1. Total electrical lighting consumption with no daylighting (KWh/sq.m./month).

2. Electrical lighting consumption during the monitoring month (KWh/sq.m./month) for June and December (and March/September if possible)

3. Percent of electrical lighting savings per month for June and December (and March/September if possible).

4. Typical weekly (and daily) lighting consumption profile of the electrical lighting control system (KWh/sq.m./ week and day).

5. Extrapolated annual electrical lighting consumption (KWh/sq.m./year).

6. Estimated annual electrical lighting savings (percent of savings and US$/sq.m./year for given utility rates).

Contribution to Indoor Illuminance

1. Typical weekly (and daily) profile per season of the indoor illuminance[4] for a daylighted zone in the space (indoor lux and outdoor lux vs. time)

2. Percent of daylight-hours where the indoor illuminance exceeds the bin indoor horizontal illuminance for a given daylighted zone during a typical week (percent of daylight-hours/week/lighting level, for the summer and winter). The bin indoor illuminance is 250, 500, and 1000 lux.

3. Typical Daylight Factors [5] for a given daylighted zone of the selected space. This is based on the measurements taken during typical overcast sky conditions. This is to reflect the regions with predominant overcast conditions, where the Daylight Factor can be used for daylighting assessment. Also, the Daylight Factor can be used as a reference level since the Daylight Factor has been widely used as a daylighting performance indicator.

5.1.2. Selection of Test Points and Daylighted Zones

Daylighted zones of the selected space should be defined prior to the selection of the measurement points. These zones should be defined based on their distance from the window, (or atrium skylight), and based on the activity in the zone. Measurement points should represent typical illuminance in each daylighted zone. The number of daylighted zones and test points depend on the dimension of the space, and on the activity.

A private office with sidelit window should not have more than 2 test points, one for each daylighted zone, one of which has to represent a dark area. The number of daylighted zones in an open plan office should be at least equal to the number of workstations in the selected space. A minimum of one test point at the working plane level (75 cm above the floor) should represent each workstation. The test point can be at center of the zone or represent a critical location of the activity, e.g. desk. A large classroom may require three zones, with three test points at each zone to represent illuminance at the front, middle, and on the back of the classroom. The test points on the sidewalls should be about 1 meter away from the walls, and measured at the working plane level (75 cm above the floor).

In an atrium space, each floor, including the atrium floor, should be considered as a separate zone. At least four test points are required in each adjacent space or floor, two on the east and two on the west. The atrium floor should include at least three test points (center, east, and west). Figure 3 shows a schematic description of test point selection.

[4] One lumen of luminous flux, uniformely incident on one square meter of area, produces an illuminance of one lux (1 lux = 10.764 footcandles) (Stein and Reynolds, p. 916).
[5] The Daylight Factor (DF) is defined as the ratio of indoor illuminance at a given point to unobstructed exterior horizontal illuminance, expressed as a percentage. It can be used with the CIE-defined overcast sky and clear sky whose distribution is fixed for the purpose of calculation. Direct sun is excluded (Stein & Reynolds, p. 979).

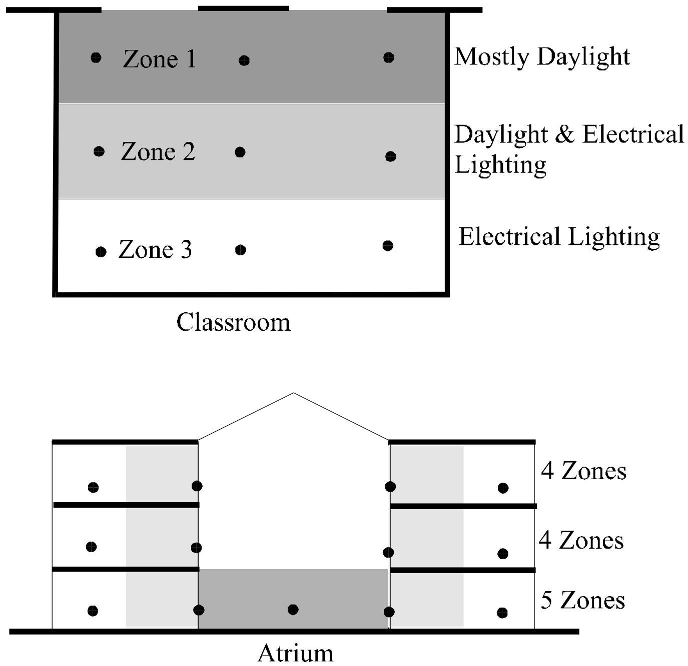

Fig. 3. Examples of typical selection of daylighting zones and test points

5.1.3. Recording Illuminance

Illuminance measurement in the selected space should be collected for three to seven consecutive days, around June 21 and December 21 (nearest possible), (and March/September 21 if possible). Illuminance should be recorded at least every two hours: for example, at 08.00, 10.00, 12.00, 14.00, 16.00, 18.00, and 20.00; or at 09.00, 11.00, 13.00, 15.00, 17.00, and 19.00. The time and sky conditions for each test measurement should be recorded. One test measurement should be conducted under overcast sky with no sun in the winter to determine the Daylight Factor. In all cases, global and indoor illuminance should be simultaneously measured.

When photocells are reading both daylight and artificial light, illuminance measurements at nighttime should also be recorded for the selected test points. This is to estimate real daylighting contribution in the daylighting space, by subtracting the artificial lighting contribution. This will also help to define the design illuminance level.

Illuminance should be recorded at the working plane level (75 cm above the floor). In most cases, fixed photocells are impractical if the building is occupied. Occupants and papers can affect illuminance recorded by detectors (if photocell is mounted on a desk). An alternative solution is to take manual measurements using a tripod, with a the photocell fastened at the top. It is important that each set of measurement should be completed very quickly, especially if the sun component is present. A four-minute test duration is recommended but, it is often impossible to meet this requirement when many manual measurements are taken in a large space. It is also necessary to record the luminaires, which are on.

5.1.4. Measuring Electricity Use

Continuous readings of electrical lighting demand on the lighting circuits of interest is the preferred method of evaluating lighting electricity use. Readings should be collected every 4 minutes or so. For an automatic on/off system or manual , current loggers can automatically monitor time -of use, and equivalent electricity use can be subsequently calculated.

5.2. Predicted Performance Level : Short-term and Annual (optional)

The objectives of the predicted performance level are:

1. to overcome the shortcomings of the monitoring phase with respect to length of monitoring (annual performance) and measuring the performance of the entire building.

2. to compare the predicted performance with the real (measured) performance. This will allow designers to estimate the extent of errors from prediction tools, and to identify the problems that prevent daylighting from reaching its full savings potential

Computer simulation, daylighting prediction methods, and rules of thumb will be used to estimate the electrical lighting consumption, daylighting contribution in the space, and impact of daylighting on thermal loads. Computer simulation will include:

Comparison with short term monitoring
1. The computer software Adeline (SUPERLITE path) or other daylighting software will be used to compute Daylight-hours when indoor horizontal illuminance is higher than the bin illuminance for each daylighted zone of the selected space. This simulation should correspond to the same monitoring week for each season.

Annual Performance
2. The computer software Adeline (SUPERLITE path) (or other daylighting software) will be used to predict the annual electrical lighting consumption of the selected space (under ideal condition). This will be compared to the one extrapolated from seasonal measurement.

3. The annual electrical lighting consumption of the all daylit zones of the building should be computed.

Daylight Factor
4. The Daylight Factor can be estimated for every daylight zone using available techniques such as the Lumen or the Daylight Factor Method for sidelighting, and available rules-of-thumb for other top-lit zone (atrium).

Thermal loads of the selected space
5. The reduction (or increase) of the annual thermal loads, from lighting and solar loads, will be computed using an energy computer package such DOE2, BLAST, TSBI, TRNSYS, or other available software. The lighting load profile should include the one measured (and extrapolated) from the measured performance level. The thermal loads should be compared to those for the same space, but with all lights on and with a window size and Solar Heat Gain Coefficient of a typical building type in the region.

5.2.1. Outputs

Expected outputs and performance indicators of the predicted performance level are:

1. Predicted percent of daylight hours when illuminance exceeds the bin illuminance value per daylit zone (percent of daylight hours/week/season/daylit zone)

2. Predicted annual lighting consumption of the selected space (KWh/sq.m./year)

3. Predicted annual lighting savings of the selected space (percent and US$/ KWh/sq.m./year based on local rates)

4. Predicted electrical lighting savings of the entire daylit spaces (percent and US$/ KWh/sq.m./year based on local rates).

5. Percent of reduction of thermal loads from daylighting (percent as compared when all lights on)

5.3. Performance Control Parameters

Performance control parameters refer to daylighting hardware and occupancy that worsen or improve the daylighting performance. The characteristics of these parameters will help explain the daylighting performance. The following measurements/checklists are recommended during the monitoring phase:

5.3.1. Fenestration

1. The overall transmittance (to visible light) of the overall fenestration may be a lot lower than that of the glazing. This overall transmittance can be estimated as the ratio of the (vertical) illuminance just inside the window to that measured just outside window. If no measurement is taken, a rough estimation should be given if there are many structural or decorative elements around the fenestration.

5.3.2. Electrical lighting system

If stepped or continuous dimming is used, characterization of input-output performance of the system is important. It is important to check the linearity of the system response to control signals and minimum and maximum dimming levels. Linearity between daylighting detector-controller should also be noted.

The location of the detectors should be carefully analyzed. It is recommended to take a few readings of “what the detector sees” and compare them with system response and illuminance measurements.

5.3.3. Occupancy Patterns

The behavioral pattern of occupants toward shading devices should be recorded. If blinds are used, a daily profile on their tilt angle (closed or horizontal) and percent of covered glass area should be recorded. Blinds can affect not only the daylighting contribution, but also affect the amount of light received by the detectors.

The behavioral pattern of occupants towards lighting control systems should recorded, especially if it is a manual system. Their behavior toward task lighting (if not monitored) is also important.

6. STEPS TO IMPLEMENT PROTOCOLS

The steps to implement the protocols are:

1. Select whole building and/or selected space (s) for monitoring.

2. Define daylit zones in the selected space (s).

3. Select test measurements (or test points) in each daylit zone.

4. Identify experimentation tools (instrumentation) for illuminance, lighting electricity use, and recording methods.

5. Select experimentation tools to account for occupancy effects (monitor occupancy and/or survey of behavior towards daylighting technology such as shading controls, lighting controls, etc.).

6. Select procedures to account for hardware control parameter effects such as the response of the electrical lighting system, blinds, etc.

7. Select data acquisition system.

8. Define monitoring schedule for the summer, winter, spring/fall and overcast sky.

9. Implement measurement:

    9.a. Conduct daytime measurements.

    9.b. Conduct nighttime measurements.

    9.c. Conduct test during an overcast day.

    9.d. Conduct test or record behavior for performance control parameters.

10. Implement tests for the response of the electrical lighting system (if applicable)

11. Acquire and analyze data according to selected outputs

12. Determine selected outputs of the monitoring phase (as specified in the protocols)

13. Extrapolate the annual electrical lighting consumption and annual electrical lighting savings

14. Compute the annual daylighting performance of the space (if applicable)

15. Compute the daylighting performance of the space for the monitoring phase

16. Compute the thermal loads with daylighting and with lights on (as specified in the protocols)

17. Determine the Daylight Factor for the overcast conditions

7. REFERENCES

Aizlewood, M.E. 1995. The Daylighting of Atria: A Review, ASHRAE Transactions, San Diego, CA.

Andersson, B., M. Adegran, T. Wenster, W. Place, R. Kammerud, and P. Albrand. 1987a. Effects of daylighting options on the energy performance of two existing passive commercial buildings, Building and Environment. 22 (1):3-12

Andersson, B., R, Hitchcock, B. Erwine, R. Kammerud, A. Seager, and A. Hildon. 1987b. Daylighting performance evaluation method: summary report. LBL-24002. Berkeley, CA: Lawrence Berkeley Laboratory.

Atif, M. R. 1994. Integrated Daylighting Systems: Potential and Limitations for Optimum Energy Savings. International daylighting workshop, Sydney, Australia, 1994.

Benya, J. R. 1983. "Light loads." Progressive Architecture, April 1984, pp. 127-132.

Benton, C. ; Warren, M. ; Selkowitz, S. ; and Jewell, J. 1989. "Lighting system performance in an innovative daylighted structure: an instrumented study." 2nd International Daylighting Conference, Long Beach, California, 1986, pp. 286-294.

Benton, C. ; Fountain, M. ; Selkowitz, S. ; and Jewell, J. 1991. Control system performance in a modern daylighted office building. Proceedings of the 22nd session of the CIE (commission Internationale de l'Eclairage), vol. 1, part 1, Melbourne, 1991, pp. 31-34.

Bordass, W., T.Heasman, A. Leaman, and M. J. Perry. 1994. Daylight use in open-plan offices: the opportunities and the fantasies. In proceedings of national lighting conference and daylighting colloquium. Cambridge, UK: Robinson College, 243-256

Building Research Establishment. 1988. Lighting control and daylight use. Building Research Establishment Digest, No. 272, London, 1986.

Building Research Station. 1960. The Permanent supplementary artificial lighting of interiors (PSALI), Building Research Digest, No. 135, H. M. S. O., London.

Engineering Interface Limited. 1994. Feasibility study of potential for electrical energy savings in Canadian office buildings using automatic controls to dim perimeter lights. Research Report for National Resources Canada/CANMET, Ottawa, Canada, 1994.

Gardner, J. B. 1984. “Daylighting cuts energy use to 19,6000 Btu per sq. ft per year.” Architectural Record, January 1984, p. 142.

Hunt, D. R. G. 1980. "Predicting artificial lighting use-a method based upon observed patterns of behaviour". Building and Environment, vol. 12, No. 1, 1980

Hunt, D.R. G., 1979. The use of artificial lighting in relation to daylight levels and occupancy. Building and Environment 14 (1) 21-33.

Hygge, S. and H. A. Lofberg, 1997. Daylighting Post-Occupancy Evaluation Procedures, IEA Task 21 Working Document

Kristensen, P.E., 1995. Daylight Europe. Proceedings Right Light Three Conference, Newcastle, pp. 3-10 (Northern Electric /IAEEL, Newcastle).UK.

Littlefair, P. J. 1984. Daylight availability for lighting controls. Proceedings CIBSE National Lighting Conference, Cambridge, UK.

Littlefair, P.J. 1990. Predicting annual lighting use in daylit buildings. Buildings & Environment 25 (1) 43-45.

Littlefair, P.J. and Aizlewood, M.E. 1996. Measuring daylight in real buildings. Proceedings of the CIBSE National Lighting Conference, Bath, UK.

Love, J. A. 1995. Field assessment of daylighting systems. Prepared for Public Works Canada (Architectural and Engineering Services), Ottawa, Canada.

Love, J. A. 1993. Daylighting estimation under real skies: further comparative studies of full-scale and model photometry. JIES 22 (2) 61-68.

Love, J.A. and M. Navvab. 1991. Daylighting estimation under real skies: a comparison of full-scale photometry, model photometry and computer simulation as techniques for daylighting prediction under real sky conditions. JIES 20 (1) 140-156.

Opdal, K. and B. Brekke. 1995. Energy Saving in Daylighting by Utilization of Daylight. Proceedings of right light three: the third European conference on energy-efficient. vol. 1 published papers. Newcastle upon Tyne, UK: Northern Electric. 67-74

Rea, M. S. 1984. “Window blind occlusion: a pilot study”. Building and Environment, Vol. 19, No. 2, 1984, pp. 133-137.

Ruck, N. 1989. “Lighting Design.” in Building Design and Human Performance, Ed. Nancy Ruck, 1989, New York : Van Nostrand Reinhold, Chapter 6, pp. 89-115.

Selkowitz, S. E. 1986. "Effective daylighting in buildings-revisited." Lighting Design & Applications, March 1986, pp. 34-47.

Selkowitz, S. E. 1989. “Evaluation of advanced glazing technologies”. in Building Design and Human Performance., Ed. Nancy Ruck, Van Nostrand Reinhold, New York, 1989, pp. 241-260.

Shanus, M. D. ; Windheim, L. S. ; Riegel, R. J. ; and Davy, K. V. “Going beyond the perimeter with daylight.” Lighting Design & Applications, March 1984, pp. 26-29.

Simmond, K. ; and Longenderfer, E. 1984. "Diamond Shamrock Corporation, Industrial Chemicals Division." Lighting Design & Applications, March 1984, pp. 26-29.

Stein, B. and John S. Reynolds. 1992. Mechanical and Electrical Equipment for Buildings, John Wiley & Sons, New York.

Usibelli, A.; Greeberg, S.; Meal, M.; Mitchell, A. ; Johnson, R.; Switzer, G.; Rubinstein, F.; and Aratesh D. 1985. “Commercial-sector conservation technologies.” Lawrence Berkeley Laboratory, Report LBL-18543.

Wolpert, J.S. 1993. "Commissioning an industrial lighting-daylighting system: added value for cutting-edge technologies." ASHRAE Transactions, vol. 99, part 2, 1993.