SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Standardisation issues related to lighting and daylighting control systems

IEA SHC Task 61 / EBC Annex 77: Integrated Solutions for Daylighting and Electric Lighting

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

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Our mission is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

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Editor: Marc Fontoynont

Authors (in alphabetical order):
Jan de Boer, Nikodem Derengowski, Marc Fontoynont, Daniel Neves Pimenta, Per Reinhold, Robert Weitlaner

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AUTHORS (in alphabetical order)

Jan DE BOER Fraunhofer Institute for Building Physics IBP Nobelstr. 12, 70569 Stuttgart Germany jan.deboer@ibp.fraunhofer.de Nikodem DERENGOWSKI BUILD - Institut for Byggeri, By og Miljø A.C. Meyers Vænge 15, 2450 København SV Denmark derengowski.nikodem@gmail.com Marc FONTOYNONT BUILD - Institut for Byggeri, By og Miljø A.C. Meyers Vænge 15, 2450 København SV Denmark mfo@build.aau.dk	Daniel NEVES PIMENTA Fraunhofer Institute for Building Physics IBP Nobelstr. 12, 70569 Stuttgart Germany daniel.neves.pimenta@ibp.fraunhofer.de Per REINHOLD Dansk Center for Lys (Danish Lighting Center) Borupvang 9, 2750 Ballerup Denmark pr@centerforlys.dk Robert WEITLANER HELLA Sonnen- und Wetterschutztechnik GmbH 9913 Abfaltersbach 125 Austria robert.weitlaner@hella.info

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PREFACE

Lighting accounts for approximately 15 % of the global electric energy consumption and 5 % of greenhouse gas emissions. Growing economies, higher user demands for quality lighting and rebound effects as a result of low priced and more versatile electric lighting continuously still lead to an absolute increase of lighting energy consumption. More light is used, often less consciously.

Especially the electric lighting market but as well the façade, daylighting und building automation sectors have seen significant technological developments in the past decade. However these sectors still act mainly independent of each other, leaving out big potentials lying in a better technology and market integration. This integration is on the one hand beneficial to providing better user-centred lighting of indoor spaces. On the other hand it can contribute significantly to the reduction of worldwide electricity consumptions and C02-emissions, which is in line with several different governmental energy efficiency and sustainability targets.

IEA SHC Task 61 / EBC Annex 77 "Integrated Solutions for daylighting and electric lighting – From Component to system efficiency" therefore pursues the goal to support and foster the better integration of electric lighting and daylighting systems including lighting controls with a main focus on the non-residential sector. This includes the following activities:

- Review relation between user perspective (needs/acceptance) and energy in the emerging age of "smart and connected lighting" for a relevant repertory of buildings.
- Consolidate findings in use cases and "personas" reflecting the behaviour of typical users.
- Based on a review of specifications concerning lighting quality, non-visual effects as well as ease of design, installation and use, provision of recommendations for energy regulations and building performance certificates.
- Assess and increase robustness of integrated daylight and electric lighting approaches technically, ecologically and economically.
- Demonstrate and verify or reject concepts in lab studies and real use cases based on performance validation protocols.
- Develop integral photometric, user comfort and energy rating models (spectral, hourly) as pre-normative work linked to relevant bodies: CIE, CEN, ISO. Initialize standardization.
- Provide decision and design guidelines incorporating virtual reality sessions. Integrate approaches into wide spread lighting design software.
- Combine competencies: Bring companies from electric lighting and façade together in workshops and specific projects. Hereby support allocation of added value of integrated solutions in the market.

To achieve this goal, the work plan of IEA SHC Task 61 / EBC Annex 77 is organized according to the following four main subtasks, which are interconnected by a joint working group:

- Subtask A: User perspective and requirements
- Subtask B: Integration and optimization of daylight and electric lighting
- Subtask C: Design support for practitioners (Tools, Standards, Guidelines)
- Subtask D: Lab and field study performance tracking
- Joint Working Group: Evaluation tool & VR Decision Guide

Subtask B focuses on the evolution of the technologies and identifies new opportunities offered by control systems for lighting and daylighting systems, with the objective to improve energy performance as well as improving operation by occupants and facility managers.

EXECUTIVE SUMMARY

Even though there are existing codes and standards regarding daylighting and electric lighting controls, they have to be constantly reviewed and updated, as the technology is growing rapidly - and so do the users' expectations. That is, in both efficiency of buildings in terms of sustainability and energy usage (utilizing advanced sensor-based systems), and also in the need for high quality of lighting at the workplaces.

The two areas – control of daylight, and control of electric lighting – are usually treated separately, which raises a question whether it is possible to combine existing knowledge and technology in attempt of creating a thorough standard or guidelines considering integration of the two areas.

This report first takes under scope existing situation in standardization of the daylight and electric lighting controls, describing available publications, user needs and current market situation. It is then followed by suggestions for control specifications taking into account challenges associated with integrated control strategy. Among others, the key issues include:

- Blocking of the sunlight penetration to reduce glare, overheating, and thermal discomfort, while at the same time increasing energy usage to compensate lighting levels with electric lighting.
- Manual override of the systems according to the user preference in juxtaposition with the automated systems defining the most efficient settings for the building performance
- Simplification of the operation to create user-friendly (and most importantly: used) systems
- … and others

The report also describes additional topics that can be challenging in standardisation of integrated lighting controls – security, calculations, and user interfaces. The security can be compromised in both digital and physical realm – either the possible hack of the system (and thus control of software and effectively of the BMS), or by physical damage to the elements of the integrated system (such as sensors or blinds).

Another topic is standardisation of the calculations – the report stresses importance of a new review of the calculation methods, considering different impacts of the integration of daylight and electric lighting control – for example, calculating the daylight intake after imposing a reduction factor coming from overheating and glare prevention.

The final topic are user interfaces. With a large influx of solutions on the market, there is perhaps a need to standardize the interaction between the user and the system, to secure a properly used and sustainable solution. Beside this publication, this is further described in reports B.1, and B.2

Contents

1 Abstract

This document proposes a review of a number of standards possibly concerning the integration of control of incoming daylight with the control of artificial light inside buildings. In fact, we identified a number of standards dealing with lighting controls, few on shading systems and hardly anything dealing with the control of the two aspects together.

The principle of linking these two aspects is rather new as it was described in report B.3. “Review of new systems and trends”.

CEN, ISI, IEEE, EIC, CIE are bodies proposing standards for products, components, protocols, interfaces and specifications. Also building regulations define rules valuing some aspects of lighting controls through target performances and calculations methods.

Manufacturers tend to develop their own proprietary solutions, and their clients would like to be able to define specifications and performance criteria when they write tenders.

This report identifies which aspects would possibly need development of standards.

2 Standards of interest for lighting/daylighting controls

CEN and IEC have issued a number of standards relevant to the issue of lighting controls, shading materials, control systems, as well as commissioning. We list them below:

- EN 14501:2021 Blinds and shutters. Thermal and visual comfort. Performance characteristics and classification. This standard is intended to be used by professionals such as blind and shutters manufacturers and engineering firms. It is a product standard.

- EN 17037 Daylight in buildings. This standard specifies elements for achieving, by means of daylight, adequate impression of lightness indoor, sufficient views, sunlight and protection against glare. It is a performance building standard.

- EN 1932:2013 External blinds and shutters. Resistance to wind loads. Method of testing and performance criteria (Product performance standard)

- EN 12045:2000 Shutters and blinds power operated. Safety in use. Measurement of the transmitted force (Product performance standard)

- EN 12216:2018 Shutters, external blinds, internal blinds. Terminology, glossary and definitions.
- EN 14500:2021. Blinds and shutters. Thermal and visual comfort. Test and calculation methods.
- EN 14501:2021 Blinds and shutters. Thermal and visual comfort - Performance characteristics and classification.

- DS/CEN/TS 15231:2006 Open data communication in building automation, controls and building management. Mapping between Lonworks and BACnet.

- EN 15193-1:2017 Energy performance of buildings - Energy requirements for lighting - Part 1: Specifications, Module M9.

- CEN/TC 169 N 1844 (proposal) Draft Decision 460_2021 Modified Transposition of ISO_TS 21274 to a CEN_TS: Commissioning of lighting systems in buildings.

- DALI IEC 62386 - the international standard for DALI technology (Communication standard).
- SMI – Standard Motor Interface, is a consistent interface for electric drives. Developed to enable connection of drives with integrated electronic circuits for applications to roller shutters and sun protection installations.
- CIE 222:2017 Decision Scheme for Lighting Controls in Non-Residential Buildings. guidelines in order to balance lighting quality, user comfort and energy efficiency in lighting controls solutions for lighting in non-residential buildings.

- EN ISO 16484 - series of International Standards under the general title *Building Automation and Control Systems (BACS)* and consists of the following parts: *Overview and Vocabulary*, *Hardware*, *Functions*, *Applications*, *Data communication – Protocol*, *Data communication - Conformance testing*, *Project specification and implementation*

There are also standards related to performance and energy, where lighting control is integrated

- DS/ISO/TS 21274:2020 (Danish) . Lys og belysning – Idriftsættelse af belysningssystemer i bygninger

- DIN V 18599 Energy efficiency of buildings - Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting.

- ISO 10916 Calculation of the impact of daylight utilization on the net and final energy demand for lighting

3 Analysis of current situation and possible needs

From the review above, it seems that the simultaneous control of daylight penetration and power to electric light is not the scope of a given standard. The technologies seem to operate with their own constraints, although HVAC systems often integrate lighting control and sun-shading controls.

Should a combined control of incoming daylight and the control of artificial light inside buildings be standardized?

But the evolution of buildings as well as building design is strongly influenced by building standards (for materials, insulation fire safety, façade systems, components, etc.). One can therefore think that a global lighting/daylighting standard could stimulate development of well-integrated solutions.

However standards can be also limiting in the way disciplines can be developed. Indeed, when it comes to wireless lighting control, numerous (endless) systems have been developed, and this opens for healthy competition. However, the downside may be that it is often almost unmanageable to maintain lighting control systems if more systems are up and running in the same premises.

Possible questions could be:

- Can we operate blinds with DALI protocols, as electric lighting
- Can we communicate to shading controls with the same wireless protocols as electric lighting (Bluetooth, Zhaga, Ocean, etc.).?

4 Possible control specifications

The difficulty in the integrated control strategy of lighting is that controls must combine a number of features such as:

- Reduce lighting power as a function of incoming daylight (optimize daylighting)
- Adjust shading system to reduce overheating
- Adjust shading system to reduce glare
- Adjust shading system to reduce thermal discomfort
- Maintain adequate view to the outside
- Allow occupants to over-ride the systems (up to a specific point)
- Put system is low energy mode in absence of occupants
- Simplify operation by facility managers
- Possibly close shutters from a centralized control system (building security)

Operation of the global systems requires to collect at any time, strategic information such as:

- Outdoor climatic conditions
- Indoor occupancy patterns

4.1 Standardization relevant to daylight/sunlight penetration?

Electric lighting controls operate with various daylight sensors, mostly in close loop, meaning that operation of blinds leads to modifying electric power of lamps, through the change in reading of the internal daylight sensor. *This aspect may require a standardization procedure for commissioning systems.*

Solutions have been proposed to fix the sensor on the façade, so it will not be influenced by operation of blinds. Here sensors often measure vertical illuminance or irradiance. An effective solution in relation to energy management, but not always in line with requirements of occupants with respect to glare control. *Here a standard could address the type of sensor to use (product specifications), the location, and he commissioning principles.*

Anticipating climatic changes can also increase energy related performance of blind control. Suggesting more advanced outdoor climate sensors. Located on various areas of a building (roof), or even on other buildings in the area or the city. Procedure suggesting real-time processing of climatic data has also been proposed. *Here standardization could link building energy management systems to meteorological data gathering organizations.*

4.2 Standardization relevant to occupant needs?

Indoor occupancy sensors are well developed, together with clock-based controls. They provide and efficient way not to use lighting electricity in unoccupied spaces. Sensors are standardized (sensitivity, spectral response). But directionality of sensitivity could be developed further (to take into account non symmetry of daylight penetration. Spaces with multiple daylight opening would require some adjustment.

Glare from window is described in EN17037 leading to specifications of light transmission of blinds. But operation of movable blinds still needs to be described in relation to this standard. Also, the integration of the duration of acceptable glare would need to be defined, as well as more globally, the maximum duration of acceptable discomfort (thermal / visual) which has been published in scientific journals.

More globally, occupants could have full control of their work environment as they have for example in their cars. This suggests a global interface gathering all information and controlling electric lights and blinds systems.

5 Standardization of controls protocols – security issues

Report IEA61-B.2 identifies (in section 5.1.2.1) a large choice of Wireless Lighting Control Systems and various types of wireless protocols and solutions. Everything points to more and more wireless control in the future, certainly when it comes to the control of the artificial light inside buildings. However, everything in life comes with a price. The more systems that go wireless, the more the risk that interference can create disturbances and nuisance. There are already many examples of failures which have been identified.

For instance, the 1997 IEEE standard for WLANs (prior to 802.11i) was rife with security weaknesses and vulnerabilities. These weaknesses were mainly a result of an inadequate security protocol known as Wired Equivalent Privacy (WEP). In June 2004, a major industry milestone for WLAN security was achieved when the IEEE's 802.11 Working Group ratified the 802.11i security extension to the original standard

There are a number of “commercially available security systems”, but here the criteria for security appears to be the difficulty of accessibility.

It can only be recommended that communication protocols are standardized and controlled, in order that nuisance as far as possible can be avoided. And controlling light is only one discipline that wishes to occupy wavelengths for communication. So, coordination what equipment can communicate on which wavelengths in the future seems to be a monumental task, but one of vast importance which must be solved. Here standardization to make wireless communication

The ISO has proposed a standard for data communication, and conformance testing of hardware proposed in building automation.:

ISO/DIS 16484-2(en) Building automation and control systems (BACS) — Part 2: Hardware

This standard is a major reference for companies developing wireless communication for their lighting control solution.

And having discussed communication, security is next (or perhaps even before communication). Making sure that lighting control systems cannot be hacked is key. Infrastructure systems, installations in power plants, hospitals, you name it – security must be of maximum importance, and here standardization also seems to be essential.

6 Standardization of calculations

Methods using approaches in standards are indeed already considered when it comes to the daylight intake into buildings. For example, as we have found, in the standard ISO 10916:2014 - Calculation of the impact of daylight utilization on the net and final energy demand for lighting mentioned above. Thus, from the scope of ISO 10916:

“This International Standard defines the calculation methodology for determining the monthly and annual amount of usable daylight penetrating non-residential buildings through vertical facades and rooflights and the impact thereof on the energy demand for electric lighting. This International Standard can be used for existing buildings and the design of new and renovated buildings.”

Considerations are for example if the daylight intake will result in a heat rise inside buildings in a magnitude, which would be unacceptable. This could mean that that the blinds control for an unacceptably long time would have to prevent free outlook through the windows to avoid the increase in temperature, thus leading to an increase in the energy consumption from the installed electrical lighting equipment.

It is probably worth while looking at ISO 10916:2014 to determine if the standard should be reviewed to see if it needs updating and to determine if it is up to date concerning today's need for optimum control of the daylight intake and outlook from buildings. We – DCL – are not very introduced as to what extend ISO 10916 is indeed used. There seem to have been a very comprehensive work behind the creation of this standard. If it is not used widely, perhaps an information campaign after a review of the standard, and also perhaps a guideline as how to use the standard could be considered.

7 Standardization of user interfaces

In other discussions with partners in the project, the lack of standardization for user interfaces came up, and the possible knock-on effect this may have on human behavior and electrical energy consumption.

Report IEA 61 B.4 User interfaces summarizes initiatives conducted to share in user interfaces common graphical details, coherent with a number of other equipment. There are for example standardized pictograms.

A good reference on this aspect is ISO/IEC ISO/IEC JTC1/SC35 Standard on user interfaces.
It is linked to a number of standards (keyboards for examples: ISO/IEC 9995-1:2009: Information technology — Keyboard layouts for text and office systems — Part 1: General principles governing keyboard layouts.

Furthermore, interfaces of smartphones tend to share a number of functionalities, leading to the possibility for interface developers of lighting controls to share the same approach, and simplify understanding by users (see examples in report IEA 61 B.4.)

The user interfaces seem to have a huge impact on how systems are used. For example, in Denmark it is determined by law that all workplace facilities with a proper daylight intake must have electrical lighting systems which are equipped with an automatically controlled daylight harvesting system. However, it seems legal to install an override also, for example in schools to create light scenes to support special educational purposes. But it seems that the legislation is lacking to address for how long these manually override situations are allowed per incident.

The "educating interfaces", providing information on the operation on energy related building components have demonstrated their potential, but they are still very rare today. The way to standardization would be related to possible specification in building energy codes of possible requirements to inform users, facility managers and occupants of the status of the building. Such an approach is used today in automobiles providing information on instantaneous and average fuel consumption helping drivers to reduce the consumption of their cars.

8 Conclusion

Standardization is required to increase the reliability and confidence in the ecosystems of lighting controls, during the design phase, installation and long-term operation.

Taking into account this review, as well as the proposals of new systems identified in report B. 3 (*New systems and trends),* we have identified some components requiring further work on their standardization. The objective is to increase confidence among stakeholders and improve reliability and performance of the global solutions.

Topic	**Detail**	**Challenges**
Sensors	Outside Sensor (open loop) and indoor sensor (closed loop)	Reliability, accuracy, design, defining number of sensors for accurate and dynamic control of different facades/areas of the building, processing of signal from different sensors (inside and outside, combining inputs from daylight, illuminance and presence sensors),
Motor	DC / AC / SMI	Reliability, noise, steps
Operation	Performance	Precision of blind control / type steps, detailed design for different areas/rooms,
Accuracy of blind controls	Time step for actions (lighting / daylighting)	Performance vs user satisfaction, tolerance issues
Commissioning procedure	On site during installation and during maintenance	Tuning of systems, training in operating and maintaining the systems,
PV powered solutions	Sizing issue	Autonomy level, storage of the power,