

PROJECT DOCUMENT

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Report on the Application of CEN Standard EN 15193 EN 15193: Energy Performance of Buildings - Energy Requirements for Lighting

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IEE-CENSE

*Leading the CEN Standards on Energy Performance of Buildings to practice
Towards effective support of the EPBD implementation and acceleration
in the EU Member States*

Supported by

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1 Executive Summary and Recommendations

1.1 Executive Summary

The development of the European CEN standard EN 15193 [1] on lighting energy can be regarded as a big step forward concerning the implementation of energy efficient lighting concepts. It offers a useful umbrella framework of different methods and ways to determine lighting energy needs. Nevertheless, the feedback from a European inquiry process within the CENSE-project (questionnaire and workshops) on acceptance and applicability of the standard suggests that further improvements should be considered within the next review phase of the standard. Editorial and structural clarifications should be tackled as well as some technical aspects, which have not yet been addressed sufficiently.

The CENSE-project was initiated by the European Commission to improve acceptance and use of the CEN standards, which were developed to analyse the energy performance of buildings, including lighting, according to the EPBD. The project's goal is to identify problems concerning the standards' contents and their implementation via questionnaires and workshops and to formulate recommendations for improvement.

Within the framework of the CENSE-project the standard EN 15193, covering the energy requirements for lighting, was investigated. The questionnaire's evaluation shows that though lighting requirements have been defined in most European countries, only few countries did actually put the CEN standard into force; also, awareness of practitioners is still low. In general, the standard is regarded as a useful umbrella document and its methods are considered to be applicable and helpful. Nevertheless, parts of the standard are rated being not easy to understand. Although many essential parameters in the determination of lighting energy needs are covered, some additional aspects should be addressed in a revised version. Providing, for instance, methods to rate lighting controls in more detail, to determine the installed power of new lighting installations and to rate the impact of sunshading devices on the lighting energy demand might help to further improve the standard's quality and acceptance.

A simple means to raise acceptance seems to lie in a review focusing on structure and editing in order to clarify and simplify parts of the document. Particularly the presentation of equations should be reorganized, for instance by adding a list of the variables used to each equation and by describing connections to other equations, making them more understandable. An example of technical aspects still to be addressed is artificial lighting, which is only taken care of in existing buildings in the current version of the standard. Consequently, an additional approach covering the lighting design in new buildings needs to be developed, and a simplified method should be included. Also the effect of lighting controls should be considered in the calculation method as well as the impact of glare and sunshading protection on lighting energy demand. By providing extra material with simplified explanations and background information, the readers' ability to understand and apply the standard could be further enhanced as well as their awareness of the methods underlying available computer software.

1.2 Recommendations

In consequence of the above results obtained by the inquiries made, the following recommendations for a review of CEN standard EN 15193 are given:

- Review of the standard's structure and editing of the equations.
 - A clear structure, which separates common procedures and national choices, is essential to make the document easily understandable. Regarding this issue, a common structure of all CEN-standards should be aimed at.
 - The current layout of the standard with numerous stand-alone equations and with a lot of detailed information in the annexes requires a lot of going back and forth in the document when applying the methodology. Especially the editing of equations is crucial. They should be fully spelled out, using common symbols, terms and definitions and be followed by a list of variables used. Input/Output-links between equations should also be provided.
 - The reduction of typing errors should be a positive side effect of the review process.
- Technical extensions of the standard's methodology, covering the following issues:
 - A simplified method to rate the installed power of new buildings in the design phase. In its current version, the standard focuses on the installed power in existing buildings only. An appropriate method is introduced in Annex A.
 - A method to rate the energy impact of sunshading systems, especially of moveable devices. In Annex B a detailed method is suggested.
 - A more distinguished scheme for daylight-responsive controls of artificial lighting. Annex C contains an applicable method.
 - Additional representative climatic data, especially for climates of the Northern latitudes.

For most of these aspects, corresponding methods have evolved within the last few years that can directly be included into the standard's annex with moderate effort. Some applicable methods are introduced in this report's Annex, as mentioned above.

- Control and revision of the benchmark values.

Research results and practical experiences show differences in the benchmark values given. These differences should be discussed and eventually be adapted. In Annex D, an exemplary graph is presented, which shows a clear difference compared to the values provided in the current version of the standard.

In addition, for a better understanding and improved application of the standard's methodology additional information material is asked for. As this is not the function of a standard, it is not considered a recommendation in this report's context. Nevertheless, possible options are to provide design guides with example calculations and background information, for instance included in software implementing the standard's method or by national organisations.

2 Introducing the CENSE-Project

The “Energy Performance of Buildings” Directive (EPBD) of the European Commission aims at allocating substantial energy saving potentials in the European building sector. In support of the EPBD, the European Commission mandated the European Committee for Standardization (CEN) to develop a set of standards providing methods which allow to analyze, optimize and rate the integrated energy performance of buildings, including lighting.

Although these standards have been available for quite a while now, many of them are not yet implemented in the Member States and most of them are hardly known among experts and practitioners. In order to improve acceptance and use of the CEN-standards and to accelerate their implementation on a national level, the project IEE-CENSE with 13 partners from eight different countries was initiated by the Commission.

Within the CENSE project, a series of questionnaires on the practical use of the CEN standards is developed and sent to contact persons in the EU Member States. In addition several presentations and workshops are held discussing the standards and their content. All these actions are aiming at the identification of specific problems arising from

- the content of the standard (i.e. degree of complexity, completeness, practical relevance, ...)
- the implementation of the standard (i.e. national regulations, no software, ...)

3 CEN standard EN 15193

CEN standard EN 15193 specifies the metering and calculation methodology to be used for the evaluation of the amount of energy used for lighting in buildings. The standard can be applied to existing buildings as well as for the design of new or renovated buildings. It also provides a benchmarking system for different building types, which makes it possible to rank the energy needs for lighting. The standard offers alternative routes to determine the energy requirement, which are shown in Figure 1. In general measuring or calculating is possible. For the latter, either the comprehensive or the quick method can be applied. The general understanding is that this CEN document provides a framework, an umbrella document, outlining general aspects, still leaving room for national variations and refinements using more detailed sub-models and methods.

The general calculation approach is based on the integration of the power consumption $p(t)$ of the artificial lighting system over time, to obtain the electric lighting energy consumed. For practical applications this relation is simplified by scaling the installed electrical power p_i with an effective operating time t_{eff} as illustrated in Figure 2. The effective operating time t_{eff} accounts for effects, which reduce the lighting energy consumption by accounting for available daylight or occupancy detection systems. The final result of the calculation procedure is the lighting energy demand of a building zone or of the whole building, expressed per square meter of floor area, either on a monthly or an annual basis. Monthly values are required to be linked to the overall CEN energy balancing scheme. The annual value is also referred to as LENI (lighting energy numerical indicator).

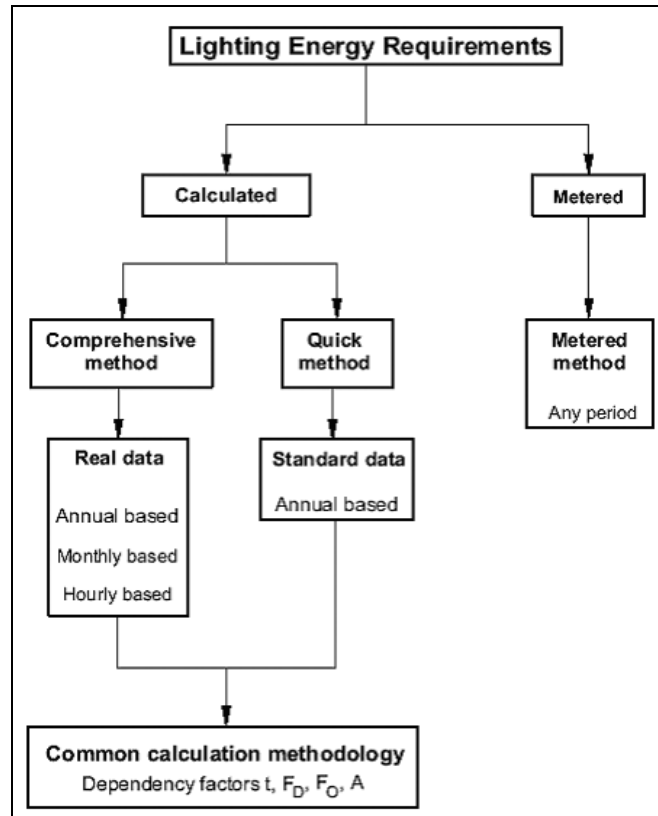


Figure 1: Flow chart illustrating the alternative routes within EN 15193 to determine energy use

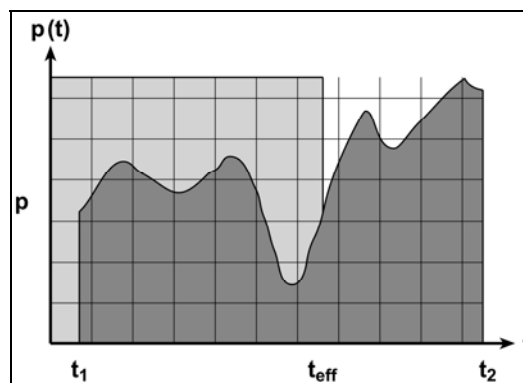


Figure 2: The concept of the effective operating time t_{eff}

4 The Questionnaire on EN 15193

One of the series' questionnaires is on the application of CEN standard "EN 15193: Energy performance of buildings - Energy requirements for lighting". It is designed in the following way: The questionnaire starts with a brief inquiry of the expert's background. With respect to the national implementation of the standard, questions about political and legal boundary conditions are covered next, followed by technical and content-based issues. The questionnaire closes with some inquiries about practical issues.

The questionnaire was sent out to contact persons identified within the CENSE project from the 27 EU Member States plus Switzerland. Representatives of the following 13 Member States returned a completed questionnaire: Belgium, Cyprus, England, France, Germany, Greece, Italy, The Netherlands, Norway, Poland, Portugal, Slovenia and Sweden. The questionnaire's evaluation will be described in the following.

Turkey and Croatia are not only candidate countries for the EU, currently there are intense discussions going on about the implementation of CEN standards there, along with high efforts undertaken to support this aim. This is why an additional answer to the questionnaire, which was received from a Turkish expert, was included in the report. Nevertheless, due to the explained special status of this country, the answers given were not included in the statistical evaluation (shown in figures 3 to 14); instead, they were added in the tables 1 to 12, which list the country-specific answers.

4.1 *The questionnaire's results*

In the following sections, the results obtained by the "Questionnaire on the application of CEN standard EN 15193: Energy performance of buildings - Energy requirements for lighting" are going to be presented. In the next four chapters, which reflect the structure of the questionnaire, each question will be discussed separately. Except for question 1, which asks for the personal background of the respondent and is thus summarized only in words, all questions are interpreted in the following manner: First a bar diagram depicts the statistical analysis, showing for how many countries each answer was given. In each of these diagrams the question asked is printed on top. A short summary follows, pointing out the main issues mentioned. Finally, the answers are listed in detail in a table, ordered alphabetically by the name of the country.

4.1.1 **Personal background**

For a better interpretation of the results and for optional feedback, the questionnaire starts with inquiries about identification and personal background, like type of profession and percentage of lighting design issues in daily working business. Also, any participation in the development of national standards and regulations is asked about. As these questions are mainly private and the answers are primarily interesting as background-information for interpretation, they are not presented in detail in this report. In general, most of the experts' background is "theoretical", i.e. related to experience made in research or in standardisation. Thus, the average percentage of lighting design issues in daily work does not exceed 25%. Furthermore, representatives of 10 countries, answering the questionnaire, are actively involved in standardisation; either in EPBD related national standards, in national building regulations or in both.

4.1.2 Political and legal boundary conditions

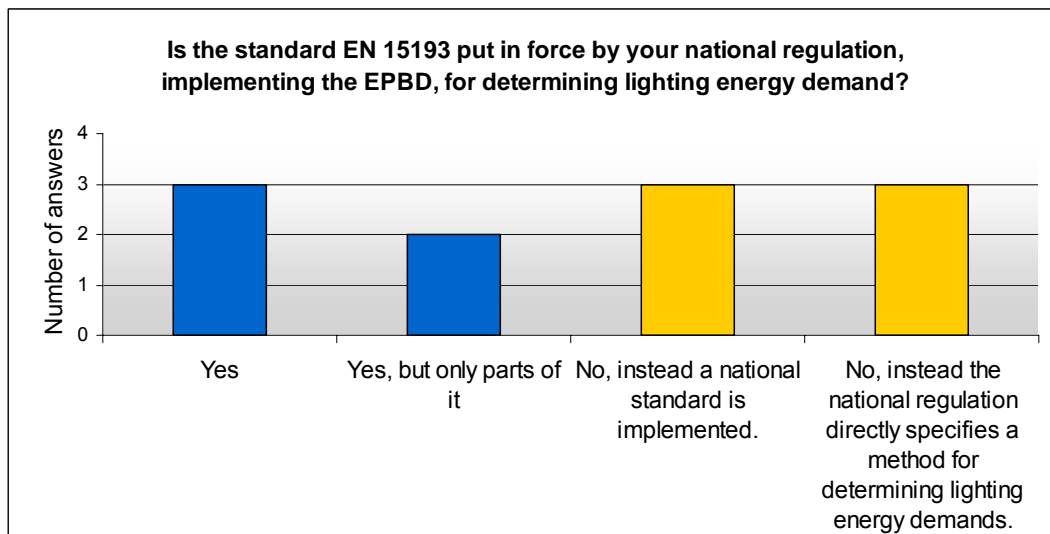


Figure 3: Diagram illustrating the responses given to question 2 of the questionnaire

Lighting requirements are officially defined in 11 out of 13 countries. But only in 5 countries, CEN standard EN 15193 is put in force, whereof 2 only implement parts of it. In 6 countries the calculation methods are specified in national documents, either in national standards or in national regulations.

Table 1: Country-specific answers to the questionnaire's question 2 in detail:

Is the standard EN 15193 put in force by your national regulation, implementing the EPBD, for determining lighting energy demand?	
Belgium	No, instead the national regulation directly specifies a method for determining lighting energy demands. The methods are just established. National regulation on energy performance is in force in Flanders since 1st January 2006.
Cyprus	Yes
England	Yes, but only parts of it. The methodology that was available at the time that the software was developed was used. It had to be rewritten in a form suitable for software and expanded to cover situations that were not included.
France	No, instead the national regulation directly specifies a method for determining lighting energy demands. The methods are already in long term use. Used in Consoclim software since 1999.
Germany	Yes. DIN V 18599 implements and references the CEN standard.
Greece	No. The national regulation implementing the EPBD does not yet define the specific lighting requirements. Any such requirements could be expected by the end of 2008/beginning 2009 in the form of Special Decrees. It is however expected that reference will be made to the standard EN 15193.

Table 1 (continued):

Italy	No, instead the national standard UNI-TS 11300 is implemented. No reference to EN 15193 is made. The national law includes a list of supporting standards (i.e. EN 13790, EN 10077...). EN 15193 is not mentioned there) The national law mentions lighting for commercial buildings only. No energy requirement is set. No calculation method is defined until now.
Netherlands	No, instead the national standard NEN 7120 is implemented. No reference to EN 15193 is made. This reply is based on the draft NEN 7120 which is in preparation and which will come into force in 2011. The quick method from EN 15193 is adopted, with a number of default values as function of building use and type of control; an explanation is added on the choices taken from and differences with EN 15193 (the explanation does not cover each and every detail, because most details of EN 15193 are in informative annexes and therefore do not require a justification that we are deviating
Norway	No, instead the national standard NS 3031:2007 is implemented. Reference to EN 15193 is made.
Poland	Yes, Polish Committee for Standardization informed that standard PN-EN 15193:2007 (oryg) is being translated into Polish and in 2009 the standard will be obligatory. Now, it is in English language.
Portugal	No, instead the national regulation directly specifies a method for determining lighting energy demands. Incipient methods included in other thermal regulations (RSECE)
Slovenia	Yes, but only parts of it. The standard present as SIST EN 15193 from December 2007. In October 2009 put in force by the national regulation on calculation methodology for building energy certificates - calculation of total energy used for lighting (note: different terms used in the methodology, with reference to the standard).
Sweden	No
Turkey	It is planned to be implemented in December 2009.

4.1.3 Technical and content-based issues

a)

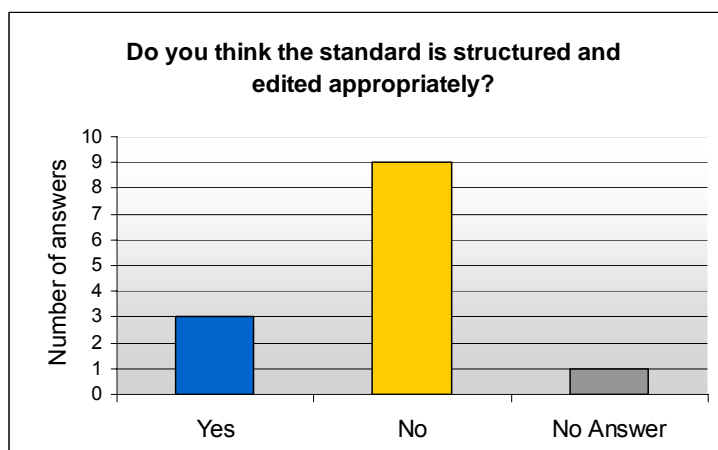


Figure 4: Diagram illustrating the responses given to question 3a) of the questionnaire

Only 3 out of 13 representatives find the standard structured and edited appropriately. Most of the questionnaire's participants criticise the high complexity of the standard and its structure being unclear and confusing with the need to go back and forth in the document to follow the methodology. As a consequence, the standard is hard to understand, especially for non-experts. Numerous equations stand alone without explanations. At least, all equations should be followed by a list of variables. In addition, editorial changes are requested and the reduction of typing errors.

Table 2: Country-specific answers to the questionnaire's question 3a) in detail:

Do you think the standard is structured and edited appropriately?	
Belgium	<p>No</p> <p>The structure full of links with annexes and other paragraphs is rather complex. If in addition, explanations in the body of the text are in a different order than the annexes to whom they refer, one could easily lose track. It seems absolutely necessary to provide a clear overview of where to find the necessary data for each determination method (e.g. a flow chart).</p> <p>Also, it's not very clear for a reader how to obtain the LENI with the comprehensive method. It is stated that in that case you should use equation 6, but it is not explained that if you want to calculate the LENI in that case, you should make a summation over different time periods, or apply equation 6 for a period $t = \text{one year}$.</p> <p>Various typing errors need to be corrected.</p> <p>The part explaining the metering should be more elaborated. The principle seems to be clear, but the practical use of this method isn't.</p>
Cyprus	Yes
England	<p>No.</p> <p>At the time that the software was developed, it had significant gaps and was too much based on tables.</p>
France	Yes
Germany	<p>No</p> <p>After shortly introducing terms and definitions, the standard starts with a couple of equations that are not very well explained. So if one is not familiar with the terms of the equations, it takes a lot of jumping forwards and backwards before being able to apply the equations. A short explanation of the symbols used in the equations, directly following those, would help. Due to the high amount of annexes, the different issues are hard to find.</p>
Greece	<p>No.</p> <p>The standard is quite complex for a non-expert to understand: many references used and equations without explanation.</p>
Italy	<p>No</p> <p>The sequence of formulas is not entirely clear. Editorially, I would expect a similar structure to other standards for uniformity within the package.</p> <p>The starting should be building need i.e. required lighting taking into account gains (solar light).</p> <p>Then the impact of the system should be evaluated</p> <ul style="list-style-type: none"> - emission efficiency could have to do with the light getting where and only where it is needed (geometry of the light) - control efficiency has to do with dimmers, auto, manual control and has been addressed - generation efficiency should cover the effect of the type of lamps (halogen, fluorescent...) <p>As far as I understood emission (geometry of the light) and generation (type of lamp) aspects are embedded in the installed power and not mentioned explicitly in the standard.</p>

Table 2 (continued):

Netherlands	<p>No</p> <p>Equation (9) is confusing, because it refers back to equations above, which are per period (which may be annual, but that is confusing). Better $W = \text{sum of } W_t$.</p> <p>In general: each equation should be followed by a list of variables and where to find the values of each variable. E.g.: separate clauses with "Boundary conditions and input data", in which clauses a distinction can be made between detailed and simple methods, with references to annexes where needed.</p>
Norway	Yes
Poland	<p>No</p> <p>Editorial improvements are necessary in general</p>
Portugal	<p>No</p> <p>It is necessary, in my opinion, to have an application guide. The matters covered, in particular daylighting aspects, are not easy to understand to "average" lighting designers.</p>
Slovenia	<p>A lack of a more logical content flow seems to be present, at least for lighting non-experts using the standard. Many terms would suit better below the equations, not in a separate paragraph, to avoid continuous scrolling through the document. It would also help if "Terms and definitions" were put into less random-looking order, and if a note would be included about where to find (or, how to calculate) certain values. For example: "3.7.1, Daylight dependency factor, (FD), /definition/, see Annex C". Some of the equations would need additional comments. Just one example: how to establish WL (part of the equation (9)) from equation (7), when the latter does not include such a term? "Note 1" below eq. (7) does provide an explanation, which again demands from user some studying of its actual meaning, and then jumping back and forth through the document.</p>
Sweden	<p>I don't know. In the building regulations and to perform an energy certificate in Sweden the total amount of needed energy is specified together with the electricity needed. It is not going into that detailed level.</p>
Turkey	<ul style="list-style-type: none"> - The standard has some points that can be hard to be understood. For example, difference between quick and Comprehensive Method and the usage purpose of them were not well defined. Additionally, it is not easy to understand the tables to be used in practise. As a conclusion, it is not practical to read and learn the standard and put it into practise in a clear way. There are problems and questions that arise at the time you want to implement the standard. - The classification of the buildings has some missing parts. The classification can cover more buildings. There are some buildings that you can not classify into any group. (Exhibition halls, culture centres, transportation buildings ... etc.)

b)

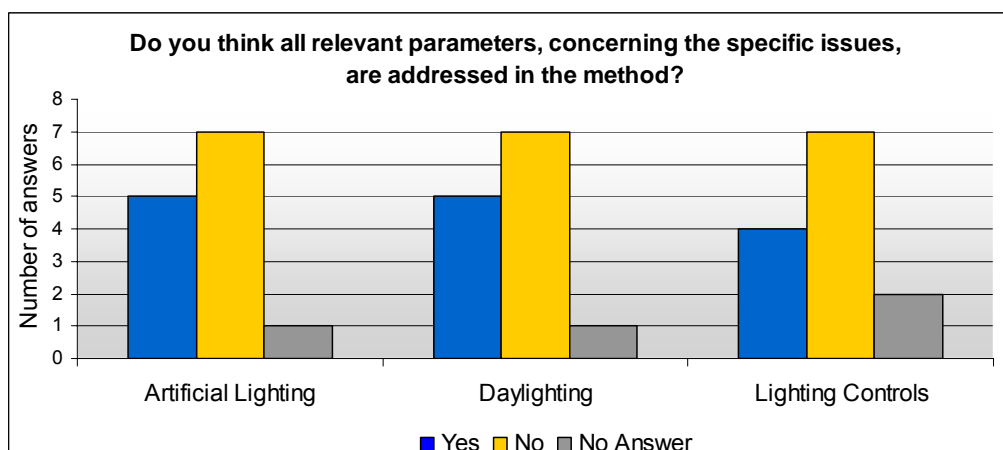


Figure 5: Diagram illustrating the responses given to question 3b) of the questionnaire

For all three specific issues only about 40% of the responses given signify that all relevant parameters are addressed in the method. Interestingly, these positive answers do not represent the same country for each issue.

Concerning artificial lighting, the main critical issues are the focus on existing buildings (installed electrical power) and the lack of a simplified method to rate new buildings already in the design phase.

Concerning daylighting, the main issue of critical comments is the missing consideration of sunshading, especially of moveable shading devices.

Concerning lighting controls, it is criticised that the effect of lighting controls is not satisfactorily covered. Thus, the hidden reference values given are not understandable and hard to apply.

Table 3: Country-specific answers to the questionnaire's question 3b) in detail:

Do you think all relevant parameters, concerning the specific issues, are addressed in the method?			
	Artificial Lighting	Daylighting	Lighting Controls
Belgium	Yes	No The influence of mobile solar protection is at this time not included and could be an improvement. However, as the method is already quite complicated, one should really think things over before including the influence of these devices in the calculations. Rather, negative default values together with a (if necessary complex) method to include the positive effects might be the better option.	No Domotics, individual algorithmic lighting, ... (most of it is already enumerated in annex H). However, cfr. Supra: this might seriously complicate the calculation method. Rather, negative default values together with a (if necessary complex) method to include the positive effects might be the better option.

Table 3 (continued):

Cyprus	No Focusing on existing buildings. Need to introduce calculation procedures for new buildings, too.	Yes	Cannot say
England	Yes Not sure that it covers display lighting adequately.	Yes	No Explicit methods for lighting controls
France	No It focuses on the assessment of the installed electrical power in existing buildings. For the new buildings, it is not yet provided. A simplified method will be helpful.	Yes	No The effect of the lighting controls is not explicit in the standard.
Germany	No The standard strongly focuses on the assessment of installed electrical power in existing buildings. For new buildings, no calculation-procedure is given, thus an additional lighting design is required. A simplified estimation method would be helpful.	No Sunshading devices, usually highly influencing the impact of daylight as a specific level of control is possible, are not covered explicitly.	No Concerning lighting controls, the standard focuses on its standby parasitic power, whereas the effect of the control systems is a bit hidden.
Greece	Yes	No Glare and sunshading are not explicitly covered.	Yes
Italy	No Technically, I read the standard rather fast and I didn't see any reference to the type of luminaires. The only input about the luminaires is the power which embeds all their characteristics (see above). ... but maybe I missed that topic...	Yes	Yes
Netherlands	Yes	Yes	No In NEN 7120 we made a distinction between day and night period for the factor for presence detection in the quick method

Table 3 (continued):

Norway	Yes	No Calculation of daylight dependency factor is an informative Annex C	Yes
Poland	No Simple procedure for lighting design is necessary.	No Data for different daylighting systems are necessary.	Yes
Portugal	No Lighting power density, among other aspects	No An appendix to the standard with full worked examples would be important, explaining, or at least exemplifying, standard daylighting design procedures. Additionally, the effect of shading devices SHOULD be included (as it is in the equivalent DIN standard). In my opinion, without taking into account the effect of non-fixed shading devices this methodology is almost useless, at least for Southern European countries.	No It is not clear for the common reader why they should use the reference values for different control systems. A simple explanation should be included. Additionally, some of the reference values do not seem to be adequate and are prone to large errors in the final energy parameters.
Slovenia	No Perhaps a more clear explanation of how to use the standard for existing and new buildings would be useful. Notes 1 and 2 on page 11 give some small hints about it ("estimation" – new construction; "establishment" – existing buildings?).	No Annex C provides information about the daylight dependency factor, and Annex H.5 provides "Daylight guidance". Annex C (and some others) is quite comprehensive, which surprises less expert users of the standard, who try to use the (seemingly simple) equations from Paragraph 4. Maybe some additional comments in the paragraph 4 would be welcome. On the other hand - regarding relevant parameters – considering the volume of the Annex C some more specific concern about shading systems would be appropriate, too.	No Having in mind the importance of these controls from the point of view of possible savings, the topic is perhaps included too "deep" or scattered in the document (C.4, Annex D, ...).
Sweden	No Answer		

Table 3 (continued):

Turkey	Yes	No - The roof top systems are so complicated. And there can be some building of which roof tops can not be calculated as given in the standard. - There should be a calculation method for calculating tD and tN values.	No Lighting controls is not given in details. The tables for Fo and Fd factors are not clear and explanatory enough.
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c)

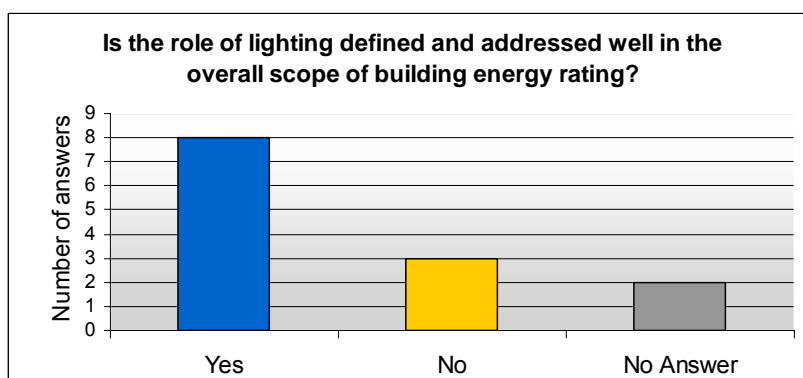


Figure 6: Diagram illustrating the responses given to question 3c) of the questionnaire

Out of the 11 answers given, 8 consider the role of lighting to be sufficiently defined and well addressed in the overall scope of building energy rating. Whereas 3 countries' representatives completely miss the connection to the building's energy need, 2 of them do not criticise that fact.

Table 4: Country-specific answers to the questionnaire's question 3c) in detail:

Is the role of lighting defined and addressed well in the overall scope of building energy rating? For instance, how to include lighting in the overall building energy balance?	
Belgium	No At this time, the standard doesn't answer these questions at all. However, it is not really the aim of the standard EN 15193 to do this, so it should not be considered as a potential improvement to elaborate this.
Cyprus	Yes
England	No Answer
France	Yes
Germany	Yes
Greece	Yes
Italy	No No separate reference to building need and effect of lighting system. They should be kept separate as for heating systems.
Netherlands	Yes
Norway	Yes

Table 4 (continued):

Poland	Yes
Portugal	No The methodology is too confusing and complex for non-daylighting related designers. The equivalent DIN standard, although more extensive, is much more understandable. Please bear in mind that, traditionally, artificial lighting designers do not have adequate knowledge of daylighting.
Slovenia	Yes
Sweden	No Answer
Turkey	No In terms of calculating LENI and adding it to overall building performance it is acceptable. But lighting is a little bit different where you should fulfil the requirements (EN12464), otherwise it will not give accurate results when you make comparisons among the buildings. The illumination levels should be checked in each room and taken into account where the artificial lighting can not fulfil the required level defined in EN 12464-1.

4.1.4 Practical Issues

4.1.4.1 General Issues

a)

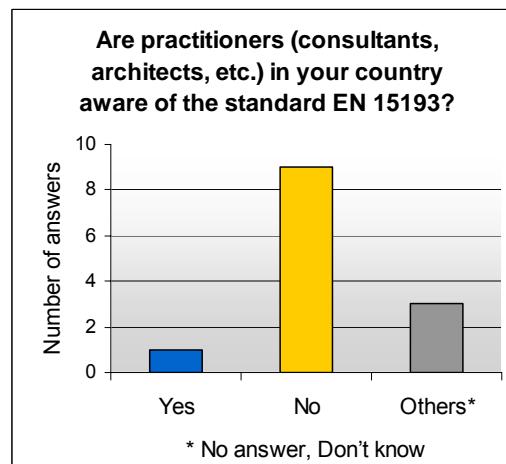


Figure 7: Diagram illustrating the responses given to question 4.1a) of the questionnaire

The distribution of the answers given (illustrated in figure 7) clearly shows that practitioners in nearly all countries are virtually not aware of the standard. Even the only positive answer was qualified by adding the comment “to some extent”.

Table 5: Country-specific answers to the questionnaire’s question 4.1a) in detail:

Are practitioners (consultants, architects, etc.) in your country aware of the standard EN 15193?	
Belgium	No Members of the Belgian Lighting Institute know of the existence of this standard, but normally don’t use it, as it is not embedded in a legal framework. The other practitioners are mainly not aware of this standard.

Table 5 (continued):

Cyprus	No
England	Don't know – in any case this is irrelevant to Building Regulations
France	No
Germany	No
Greece	No
Italy	No
Netherlands	No answer
Norway	Yes, to some extent. Steadily increasing due to courses run for national light designers.
Poland	No
Portugal	No
Slovenia	No In theory, since the energy certificates' methodology (referencing this standard) is in place since 10/2009 practitioners will have to become acquainted with the standard. It is of course possible that if this subject is included in a specific software application, no concrete knowledge of the standard will be needed. In general, only a minority of practitioners is familiar with the standard at the moment, as its use had not been obligatory in the past (from 2007).
Sweden	No Answer
Turkey	No It is very new in Turkey just to be implemented in December 2009.

b)

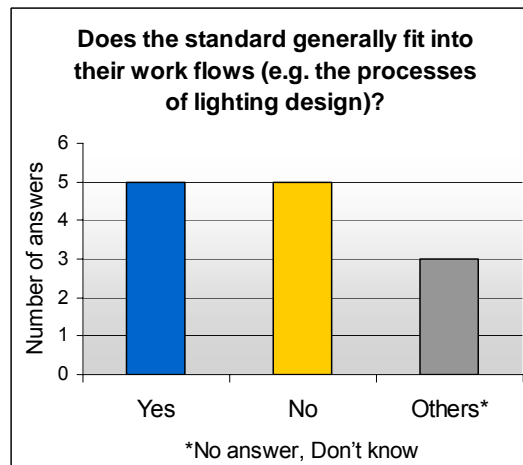


Figure 8: Diagram illustrating the responses given to question 4.1b) of the questionnaire

The opinion about the standard generally fitting into the work flows of the practitioners is balanced, although the answers are rarely straight forward. The positive ratings are mainly followed by restrictions, for instance with regard to sizing, to optimisation or in cases, where a consulting group is involved. Also, those countries voting with “No” relativize their answers by mentioning aspects like the existence of alternatives or like existing thresholds determining the dimensioning.

Table 6: Country-specific answers to the questionnaire's question 4.1b) in detail:

Does the standard generally fit into their work flows (e.g. the processes of lighting design)?	
Belgium	No No legal framework makes a reference to it and the regulation offers an alternative. Only one manufacturer active on the Belgian market makes reference to the LENI, but as another scale is used dependent on the application field (see figure), it might not always be quite clear for the layman.
Cyprus	No
England	Don't know – in any case this is irrelevant to Building Regulations
France	Yes, for sizing of the lighting installation
Germany	Yes, the standard allows to do an energy analysis of the design, helping to optimize the lighting installations.
Greece	No, lighting has not been key priority in building design up to now
Italy	No As far as I know the designers have to guarantee the luminous flux according to the use of each area. So, they are concerned with dimensioning, not with consequent energy performance (of course some will think about energy performance but on a voluntary basis only).
Netherlands	No Answer
Norway	Yes, in those cases where there is a consulting group doing the planning.
Poland	Yes
Portugal	No
Slovenia	Yes, the only question is if they actually know about it and if they see it as a tool for system optimisation.
Sweden	No Answer
Turkey	No, the processes of lighting design are quite different in Turkey right now. Designers do not deal with energy performance indeed.

c)

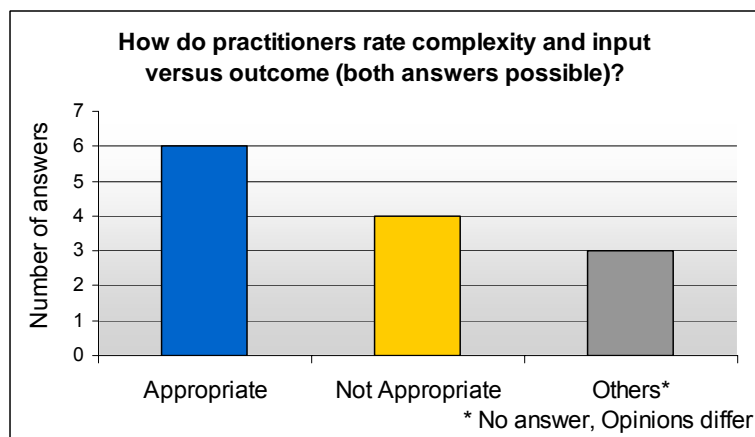


Figure 9: Diagram illustrating the responses given to question 4.1c) of the questionnaire

In general, most of the experts rate complexity and input versus outcome to be appropriate, but for some aspects the level of detail needs to be adapted. For instance, simplification is required for the complicated daylight method, whereas the level of detail should be enhanced regarding the effect of shading devices or describing improvable lighting aspects.

Table 7: Country-specific answers to the questionnaire's question 4.1c) in detail:

How do practitioners rate complexity and input vs. outcome (both answers possible)?	
Belgium	In general appropriate, but simplification needed, especially for daylight, the method is rather complicated compared with the gains you can obtain.
Cyprus	No Answer
England	Again, this does not seem to be a question that has much bearing in regulatory compliance (which is significantly different from design. A lack of recognition of this difference is a weakness in most of the EPBD standards). As far as use of compliance software is concerned, opinions differ but seem to be broadly acceptable. Concerns have been expressed about the lack of visibility of the assumptions, but this has now been addressed.
France	Appropriate
Germany	Appropriate
Greece	<i>Both answers given without further comments</i>
Italy	In general appropriate, but the level of detail should be enhanced regarding: Showing which aspect of lighting could be improved (see comment on missing emission and generation data).
Netherlands	No Answer
Norway	No Answer
Poland	Appropriate
Portugal	Not Appropriate, the level of detail should be enhanced regarding: the effect of shading devices, for instance
Slovenia	NOTE: Not enough practical experience to provide generalized answers to this question. But, considering usual feedback in such cases, a majority would be in favour of certain simplifications (unless some user-friendly software is available, so that only simple input parameters are needed, or similar).

Table 7 (continued):

Sweden	No Answer
Turkey	No Answer

d)

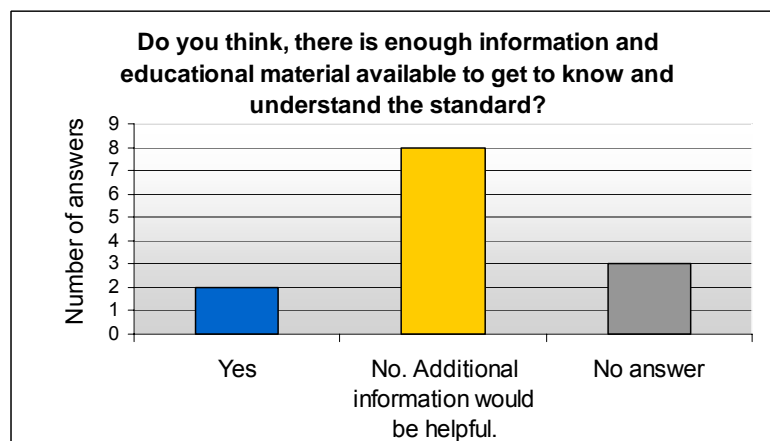


Figure 10: Diagram illustrating the responses given to question 4d) of the questionnaire

Only 2 out of 10 answers given imply that there is enough information and educational material available to get to know and understand the standard. 8 countries think additional information would be helpful. Especially a design guide with examples is asked for (mentioned in all 8 answers) as well as technical and theoretical background information (asked for in 6 cases).

Table 8: Country-specific answers to the questionnaire's question 4.1d) in detail:

Do you think, there is enough information and educational material available to get to know and understand the standard?	
Belgium	No (almost no neutral information is available) - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>
Cyprus	Yes
England	Again, this seems to imply that the standard will be directly referred to in Building Regulations. This is not so. I imagine that, as a design tool, some training would be needed.
France	No - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>
Germany	No - <i>a design guide with examples</i>
Greece	No - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>
Italy	No - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>
Netherlands	No Answer

Table 8 (continued):

Norway	Yes
Poland	No <ul style="list-style-type: none"> - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>
Portugal	No <ul style="list-style-type: none"> - <i>technical and theoretical background information</i> - <i>a design guide with examples</i> - <i>other: specific publications on daylighting and daylight climate information</i>
Slovenia	No <ul style="list-style-type: none"> - <i>a design guide with examples</i>
Sweden	No Answer
Turkey	No <ul style="list-style-type: none"> - <i>technical and theoretical background information</i> - <i>a design guide with examples</i>

4.1.4.2 Software

a)

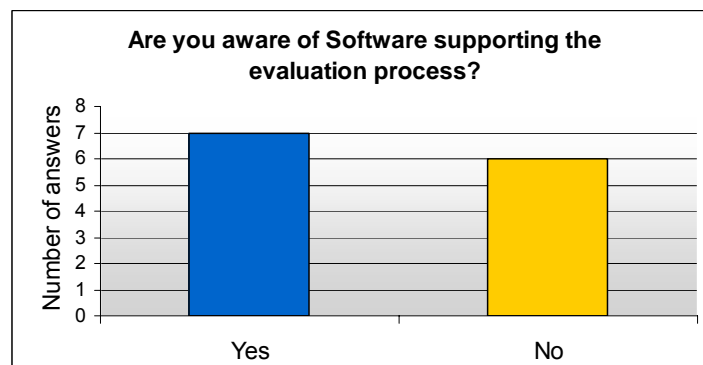


Figure 11: Diagram illustrating the responses given to question 4.2a) of the questionnaire

About half of the questionnaire's participants from the 13 European countries are aware of software supporting the evaluation process. Especially "Dialux" and "Relux" are known quite well, both being mentioned three times. Additionally, in 3 countries software supporting the specific national standards was developed. Nevertheless, there are still 6 countries not knowing any appropriate software tools.

Table 9: Country-specific answers to the questionnaire's question 4.2a) in detail:

Are you aware of Software supporting the evaluation process?	
Belgium	Yes: Dialux, Relux, ELC (Etap Lighting Calculation), Energy performance calculation software
Cyprus	No
England	Yes: In the UK, SBEM is the free-issue tool for non-dwellings but there are several other approved tools.

Table 9 (continued):

France	Yes: Dialux
Germany	Yes: ibp 18599 (rating of the energy performance of a building, including lighting); Dialux, Relux (calculating the lighting energy demand)
Greece	No
Italy	No
Netherlands	Yes: For evaluation of NEN 7120 by the standardisation committee a software tool has been developed, based on EPA-NR
Norway	No, but the most common softwares for calculating and designing are well known and in daily use, and to some extent include energy calculation.
Poland	No
Portugal	Yes: Relux (not yet available)
Slovenia	Yes: Revised and upgraded building energy rating software in preparation by a few companies at the moment (11/2009) in Slovenia
Sweden	No
Turkey	Yes: DiaLux and Relux

b)

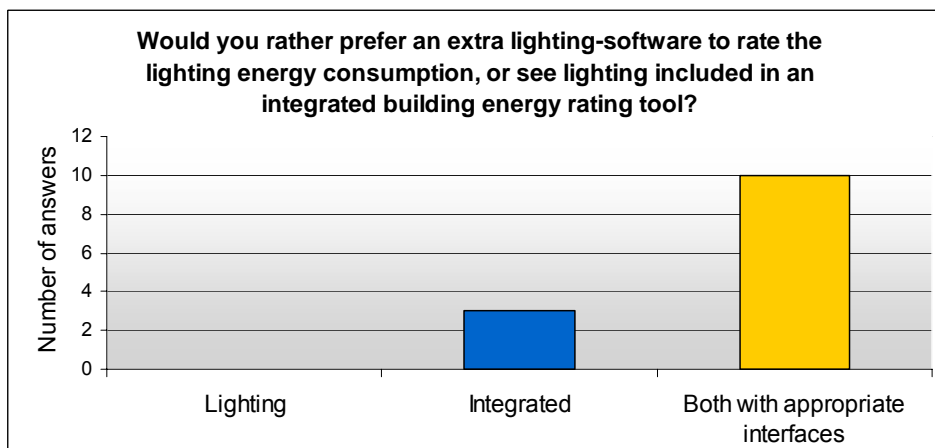


Figure 12: Diagram illustrating the responses given to question 4.2b) of the questionnaire

As computer software is nowadays commonly used in almost all fields, there is no question about developing an appropriate software tool, but rather how to organize and structure that software. In principle, two different options are possible: an extra lighting-software to rate the lighting energy consumption or an integrated building energy rating tool, including lighting. 10 out of 13 respondents consider the implementation of both options with appropriate interfaces to be the best solution. Three countries find the sole existence of an integrated software sufficient, as that's what the EPBD requires and because the highly time consuming definition of the building geometry needs to be given only once in this case.

Table 10: Country-specific answers to the questionnaire's question 4.2b) in detail:

Would you rather prefer an extra lighting-software to rate the lighting energy consumption, or see lighting included in an integrated building energy rating tool?	
Belgium	Both with appropriate interfaces More simplified in integrated tool, more detailed in-depth analysis possible with lighting-software.
Cyprus	Both with appropriate interfaces
England	Integrated EPBD requires an integrated calculation. For regulatory purposes, I think that is correct.
France	Both with appropriate interfaces
Germany	Both with appropriate interfaces
Greece	Both with appropriate interfaces
Italy	Integrated The most timeconsuming task is usually defining the building geometry. This information should be given only once.
Netherlands	Integrated
Norway	Both with appropriate interfaces The use of EN 15232 describing the impact of building automation is essential.
Poland	Both with appropriate interfaces
Portugal	Both with appropriate interfaces
Slovenia	Both with appropriate interfaces
Sweden	Both with appropriate interfaces
Turkey	Both with appropriate interfaces

c)

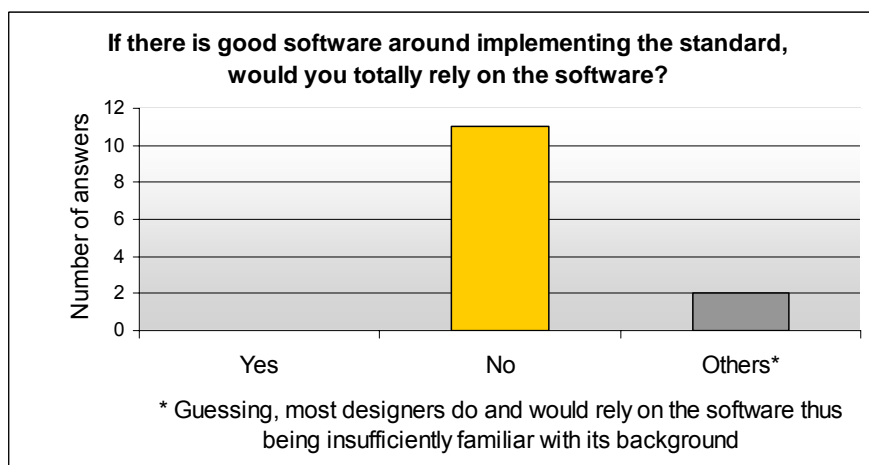


Figure 13: Diagram illustrating the responses given to question 4.2c) of the questionnaire

Virtually all answers imply that no software will be used without at least obtaining a copy of the standard to get a general idea of the methods behind the software. Nevertheless, doubts about the practical use of the software without bothering too much about the standard itself are expressed. A compromise could be found by providing simplified documents, explaining the background of the software's methods.

Table 11: Country-specific answers to the questionnaire's question 4.2c) in detail:

If there is good software around implementing the standard, would you totally rely on the software?	
Belgium	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software More preferable would be documents/books with technical and/or theoretical background information.
Cyprus	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
England	The general feeling amongst lighting professionals seems to be that they are insufficiently familiar with the assumptions of the software (which, for SBEM, generally follow the standard as it existed when the software was written).
France	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Germany	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Greece	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Italy	This is really personal opinion. In Italy I guess that most designers would rely on the software.
Netherlands	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software For daily practice the standard would not be used, only the software; but for application of the "principle of equivalence" the standard will be used
Norway	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Poland	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Portugal	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Slovenia	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Sweden	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software
Turkey	No, I would at least obtain a copy of the standard to get a general idea of the methods behind the software Especially as cases may occur, where a modification of the software for specific conditions will be needed

d)

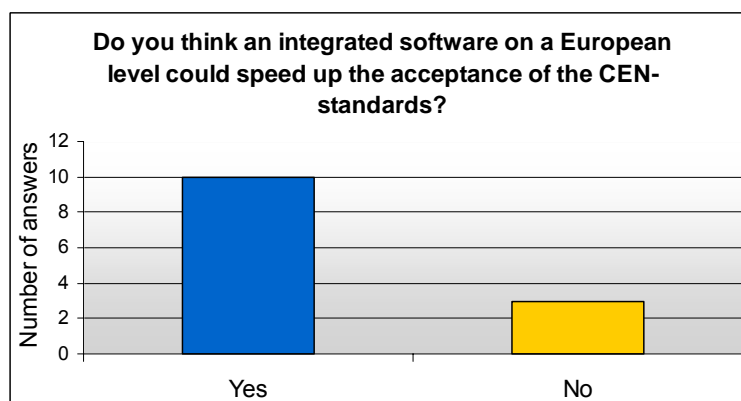


Figure 14: Diagram illustrating the responses given to question 4.2d) of the questionnaire

10 out of 13 countries agree that an integrated software on a European level could speed up the acceptance of the CEN standards. But difficulties in developing such a nationwide software are mentioned. Argumentation against the European software is based on the fact that it might be too time-consuming and too late, as many country-specific software tools have already been developed and are already in use.

Table 12: Country-specific answers to the questionnaire's question 4.2c) in detail:

Do you think an integrated software on a European level could speed up the acceptance of the CEN standards?	
Belgium	No: It might have worked, but now it seems too late, as in many countries a regulation (+ software) is already in force. At this time, the (huge financial) effort that comes with the development of such an integrated software might not lead to the wanted result.
Cyprus	Yes
England	No: I think it would take several decades to get acceptance of common software. Building Regulation structures and practices differ widely between Member States and are often deeply embedded (in the sense that many people are familiar with them)
France	Yes
Germany	Yes, as the application of computer software is very common in all kinds of energy rating, appropriate software would definitely help to make the standard better known.
Greece	No
Italy	Yes
Netherlands	Yes, but the main differences will be in the national choices of input data □ how to converge in that respect seems more urgent; the detailed method for daylighting (annex C) is adopted in NEN 7120 (by adapting existing NL method (NEN 2916) more or less to annex C of prEN 15193), but in normal practice this detailed method will not be used; instead we offer a default value for the daylight zone, as function of building use.
Norway	Yes, it will solve the needs for a uniform, independent and transparent calculation throughout Europe.

Table 12 (continued):

Poland	Yes
Portugal	Yes
Slovenia	Yes, but with careful consideration depending on the subjects. In some cases a “universal” tool is just not possible because of various national methods, prescribed specific boundary conditions, standards being put into force only partially etc.
Sweden	Yes
Turkey	Yes But it should allow for modification according to national conditions

4.2 Evaluation of the questionnaire

The evaluation of the questionnaire on the application of CEN standard “EN 15193: Energy performance of buildings - Energy requirements for lighting” [1] can be summarized as follows.

In 11 out of the participating 13 EU Member States, lighting requirements are considered in energy rating of buildings and are defined in national standards or regulations. But in only 5 countries CEN standard EN 15193 has completely or partly been put into force. In general it seems that practitioners in nearly all countries are virtually not aware of the existence of the CEN standard. In addition, it does not fit into their work flows (or only partially).

Concerning technical and content-based issues, the main points of criticism are the standard’s structure being unclear, its high degree of complexity and its inaccurate editing. Also the standard is rated being hard to understand, especially for non-experts, amongst others, due to the numerous equations standing alone without explanations. Evaluating the following specific issues, the opinions differ and several problems are stated. Concerning artificial lighting, the main issues are the focus on existing buildings (installed electrical power) and the lack of a simplified method for rating installations in the design stage. Concerning daylighting, the missing consideration of glare and sunshading is criticised. The explicit coverage of the effect of lighting controls is completely lacking. Nevertheless, the role of lighting seems to be defined and addressed well in the overall scope of building energy rating.

In general, the standard’s methods are considered to be applicable and helpful, as complexity and input versus outcome are rated to be appropriate by most of the countries. Nevertheless, for some aspects the level of detail needs to be enhanced whereas others are found to be too complicated. Also, providing additional information is considered being essential for the application of the standard. Especially technical and theoretical background information and a design guide with examples are asked for.

Discussing calculation software, the following aspects can be distinguished: about half of the representatives of the European countries are aware of software supporting the evaluation process, especially “Dialux” and “Relux” are known quite well. In addition, national software tools supporting the specific national standards were developed in several countries. Concerning the development of further software tools, most countries support both, an extra lighting-software to rate the lighting energy consumption and an additional integrated building energy rating tool including lighting. The advantage of the integrated software is that the highly time-consuming definition of the building’s geometry needs to be given only once. The common danger of applying computer software, using the programme without bothering about the standard’s method is rated low, as most experts state they would at least obtain a copy of the standard. Nevertheless, doubts concerning the practical use of the software are announced as reality often proves the opposite. The common opinion about the development of an integrated software on a European level is that this would speed up the acceptance of the CEN standards. But the argument appears, this might be much too time-consuming and too late, as many country-specific software tools have already been developed and are already in use.

5 Presentations and Workshops on EN 15193

5.1 Presentations

On several occasions, presentations on the CEN-standard EN 15193 were held within the CENSE-project, for example in January 2009 on a committee of "ZVEI", the German Electrical and Electronic Manufacturers' Association and in September 2009 at "LUX 2009", an important and well known lighting conference in Istanbul, Turkey. Despite the discussions usually following these presentations, which are normally quite short and do not go into much detail, these presentations can clearly be seen as a one-way information. Nevertheless, they are highly important in the context of the CENSE-project, as they are a good opportunity to increase awareness of and knowledge about the CEN-standards.

The content of the presentations consisted of the description of the standard and its methodology, the evaluation and results of the questionnaire and some additional background information about CEN and CENSE. The low awareness of the standard, which was identified by the questionnaire, could also be recognized in the audience listening to the presentations. Nevertheless, a high interest in the standard's content and in the work of the CENSE-project was signaled. Those participants who knew the standard mainly agreed with the results of the questionnaire's inquiry as far as they gave an opinion.

The presentation in Istanbul revealed a high interest of Turkey in the CEN-standards. As this country has not been dealing with the energy performance of buildings, which includes the rating of lighting, a big chance for the implementation and application of the set of CEN-standards can be recognized there.

5.2 Workshops

In contrast to presentations, which primarily aim at informing about the CENSE-project and the CEN-standards, workshops focus on discussions with the intention to receive feedback and/or further results on the issue. For this purpose, the questionnaire's evaluation was suitable to serve as a basis for an intense discussion. In particular, it was tried to identify and discuss problems arising from the content of the standard and its implementation. Due to the personal way of communication an open discussion in greater detail was possible, compared to the restricted form of the written questionnaire. Nevertheless, the conclusions derived from all the workshops held on the lighting standard EN 15193 were generally the same as those from the questionnaire, apart from some points, where additional observations and experiences were supplemented. Consequently, as the questionnaire's results were confirmed, they can be considered to be relevant.

5.2.1 Workshop at the Concerted Action Meeting

A joint initiative of the EU Member States and the European Commission, the Concerted Action EPBD was launched in 2005. It involves those representatives of national ministries or their affiliated institutions charged with preparing the technical, legal and administrative framework for the Energy Performance of Buildings Directive, EPBD (2002/91/EC) in each country. The key aim is to enhance the sharing of information and experiences from national adoption and implementation of this important European legislation. This makes the meeting a suitable platform to present and discuss intermediate results of the CENSE-project.

Making use of this good opportunity, a CENSE-workshop took place at the Concerted Action Meeting in December 2008 in Prague, with 44 participants from 28 different European countries, consisting of 12 policy makers and 32 advisers to policy makers. The workshop started with general information about the CENSE-project, its background, aims and first results, before several issues were covered in greater detail, including the lighting standard EN 15193. The reason for choosing this standard as example is the big energy saving potential that is latent in lighting and in the promotion of efficient use of daylight. For all issues, in addition to the speaker of the CENSE-project, two country-presentations from different European states were held, introducing experiences made with the implementation of CEN-standards and the national or personal evaluation of the specific standards' content.

In conclusion, the complete CENSE-workshop block within the Concerted Action Meeting underlined the high importance of the CEN-standards, as a basis for a Europe-wide common method, despite the existing problems in awareness, implementation and content, which need to be addressed. Here, the CENSE-project will play an important role. Regarding the content of EN 15193, the results of the questionnaire were illustrated and approved by the countries' presentations as well as by the participants. Special attention was given to the standard's focus on existing buildings. In this context, the urgent need to extend the standard for applications in the planning state of a building was clearly addressed by the participants.

5.2.2 Workshop in conjunction with the CEN/TC 169 meeting

The work within CEN, the European Committee for Standardization, is divided in several Technical Committees (TC), each covering a specific technical issue. CEN/TC 169 "Light and Lighting" covers standardization in the field of vision, photometry and colorimetry, involving natural and man-made radiation over the UV, the visible and the IR regions of the spectrum, and application subjects covering all usages of light, indoors and outdoors, including environmental and aesthetic effects.

A CENSE-Workshop for interested members of this Technical Committee took place in Milano on October, 12th 2009, one day before the TC-meeting at the same place. 15 committee members from several European countries participated. As the workshop's participants are directly involved with CEN-standardization, this workshop was a special one, which would not have been possible at an earlier stage of the project. Basically, the recommendations that were intended to be given at the end of the CENSE-project were already presented and discussed. Consequently, the participants' reactions and comments were of special interest, evaluating the quality of the project's work as well as the concrete recommendations given. Also, the participants' good knowledge of the standard's content led to a particularly high quality and depth of the discussion.

The final results of the workshop included the repeated approval of the questionnaire's findings, which also directly encouraged the work of the CENSE project; on the other hand, another important additional aspect was detected and discussed. The benchmarking values presented in the standard were recognized to be too high compared to values obtained from research and practical experience by the participants. Consequently, an additional recommendation could be formulated, namely to review the benchmarking system provided.

In conclusion, the workshop (which could be interpreted as a final rehearsal - what made it particularly crucial) approved and supported the recommendations derived within the work of the CENSE-project. In addition most of the conclusions derived could be concretised, which then lead to the formulation of specific recommendations, the final goal of the project. Workshop participants also agreed that there is a strong need to add these improvements to the standard.

ANNEXES

In the following Annexes A - D some methods will be introduced that are suited to integrate those aspects that have not been sufficiently covered (or not considered at all) in the CEN standard EN 15193. They are meant to serve as precise suggestions for the required changes that were identified during the inquiries made by means of a questionnaire and in workshops within the CENSE-project, as described in clause 4.1.3 and summarized in the recommendations (clause 1.2). Following the structure of EN 15193, the methods introduced should be integrated in the standard's annexes. A remark is given at the beginning of each of the following annexes, where exactly to include the introduced methods in the CEN-standard.

Most of the following annexes contain comments written in italic letters, which suggest to include additional information or to provide default values.

Annex A: Determination of electrical power in new installations

In the following, two methods for the determination of electrical power in new installations are introduced. They are based on the methodology developed for existing standards [2, 3, 4]. Both methods are simplified approaches to determine electrical power requirements, sufficiently balancing the relation between effort and accuracy, as shown in figure A.1. In consequence, they are not meant to be used as a substitute for electrical power requirement calculations when designing the electrical installations. The electrical power requirement is therefore called the electrical evaluation power in the following.

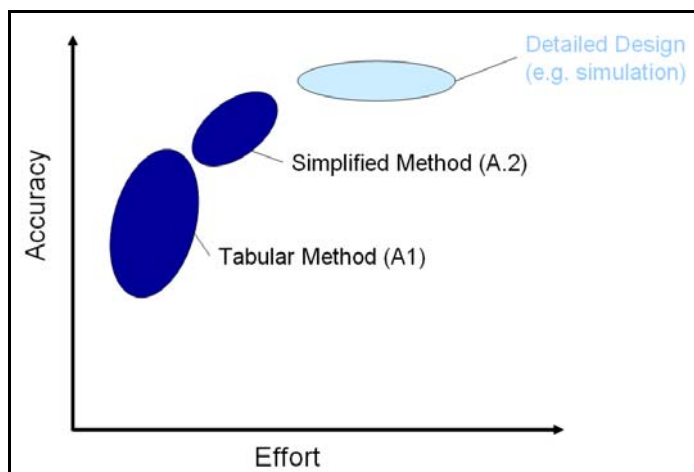


Figure A.1: Illustration showing the relation between the accuracy of different methods and the effort required.

In its current version, CEN standard EN 15193 focuses on the measurement of electrical power. Appropriate methods are described in the standard's Annex B. Thus, it would either be possible to extend this Annex B by a second part, covering the calculation method. Alternatively, an additional Annex C could be included.

A.1) Tabular Method

As shown in Table A.1, a distinction is made between three illumination types, which result in different electrical evaluation power values. The values in the table are calculation values $p_{j,lx}$ for the specific electric evaluation power in relation to the net floor area and the maintained illuminance \bar{E}_m at the work plane. The values are given for tubular fluorescent lamps with electronic ballasts (EB).

Table A.1: Calculation values of the specific electrical evaluation power $p_{j,lx}$ in relation to the floor area per lx of maintained illuminance at the work plane, for luminaires with tubular fluorescent lamps and electronic ballast (EB)

Illumination type	Specific electrical evaluation power $p_{j,lx}$ W/(m ² ·x)
Direct	0,05
Direct/indirect	0,06
Indirect	0,10

The specific electrical evaluation power can be derived from the $p_{j,lx}$ values as follows:

$$p_j = p_{j,lx} \times \bar{E}_m \times k_A \times k_L \times k_R$$

where

- \bar{E}_m is the maintained illuminance
- k_A is the reduction factor to account for the proportion of the task area;
- k_L is the correction factor taking into account the type of lamp
(for lamps other than tubular fluorescent lamps from Table 2)
- k_R is the correction factor taking into account the type of space, from Table 3.

Where lighting systems do not use tubular fluorescent lamps with EB, factors k_L from Table A.2 shall be applied to take into account the type of lamp used as a light source. In such cases the specific evaluation power $p_{j,lx}$ for the respective type of illumination from Table A.1 shall be used. All types of gas discharge lamps such as low-pressure or low-intensity discharge lamps (also called “fluorescent tubes”) and high-pressure or high-intensity discharge lamps shall always be operated in conjunction with ballasts due to the necessity of limiting the current. Certain types of discharge lamps, such as T5 lamps with a diameter of 16 mm can only be operated with EBs. Daylight-responsive lighting control (constant illumination control) can only be achieved by using dimmable electronic ballast circuits.

Comment:

Typical maintained illuminance values \bar{E}_m for various usage profiles should be specified. Values may be reduced by a factor k_A to take the task area into account. Values of k_A should be provided, either by tables for simplified calculations or to be determined in detail by applying corresponding equations.

Table A.2: Correction factor k_L to account for different types of lamp (with reference to Table A.1)

Type of lamp	Factor k_L			
	Ballast			
	–	EB ^a	LLB ^b	CB ^c
Incandescent	6	–	–	–
Tungsten halogen	5	–	–	–
Tubular fluorescent	–	1,0	1,14	1,24
Compact fluorescent, with external EB	–	1,2	1,4	1,5
Compact fluorescent, with integrated EB	–	1,6	–	–
Metal halide high-intensity discharge	–	0,86	–	1
High-pressure sodium vapour	–	–	–	0,8
High-pressure mercury vapour	–	–	–	1,7

^a EB: Electronic ballast.
^b LLB: Low loss ballast.
^c CB: Conventional ballast.

The effect of the space geometry shall be taken into account by applying the correction factor k_R as a function of the room index k from Table A.3. If the geometry of representative spaces is known in more detail, the room index can be determined as follows:

$$k = \frac{a_R \times b_R}{h'_R \times (b_R + a_R)}$$

where

- a_R is the depth of the space;
- b_R is the width of the space;
- h'_R is the difference between the height of the lighting level and the work plane (see figure 1)

If the calculation results in a room index of less than 0.6, a value of $k = 0.6$ shall be used for simplified calculations. Figure A.2 shows how the value of h'_R is determined.

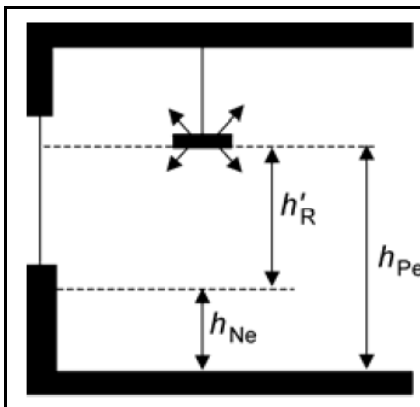

 Figure A.2: Determination of height h'_R (schematic diagram)

Table A.3: Correction factor k_R to account for the effect of the space geometry in relation to the room index k

Illumination type	Correction factor k_R											
	Room index k											
	0,6	0,7	0,8	0,9	1	1,25	1,5	2	2,5	3	4	5
Direct	1,08	0,97	0,89	0,82	0,77	0,68	0,63	0,58	0,55	0,53	0,51	0,48
Direct/indirect	1,3	1,17	1,06	0,97	0,90	0,79	0,72	0,64	0,58	0,56	0,53	0,53
Indirect	1,46	1,25	1,08	0,95	0,85	0,69	0,60	0,52	0,47	0,44	0,42	0,39
NOTE Intermediate values can be obtained by interpolation of the room index values.												

Comment:

Typical values of the room index for various usage profiles should be provided.

A.2) Simplified Utilization Factor Method

As an alternative to the method A.1) described above, the following method can be used to determine the specific electrical evaluation power in relation to the floor area of the evaluation area.

$$p_j = \frac{k_A \times \bar{E}_m}{WF \times \eta_S \times \eta_{LB} \times \eta_R}$$

where

- p_j is the electrical evaluation power in relation to the floor area for artificial lighting of the evaluation area;
- k_A is the reduction factor to take into account the task area;
- WF is the maintenance factor which takes into account system aging processes up to the time of the next maintenance;
- η_S is the luminous efficacy of the light source and the associated operating devices used;
- η_{LB} is the light output ratio (luminaire efficiency) of the type of luminaire used;
- η_R is the utilization factor from Table A.4.

In the above equation, the characteristic parameters of the individual lamps and luminaires are usually given in manufacturers' datasheets. Utilization factors as a function of the illumination type, luminaire, space reflectance and room index can be found in technical publications. For simplified estimates, the utilization factors η_R for three types of lighting ("direct", "direct/indirect" and "indirect") given in Table A.4 can be used. The characteristic parameter in this case is the relative luminous flux φ_u into the lower half-space of a luminaire. The values are referred to the standard values of the light reflectance combination of the boundary surfaces of the space, i.e. 0.2 for floors, 0.5 for the walls and 0.7 for the ceiling. The values can be used for estimates of other reflectances to facilitate the calculation procedures. If various types of luminaires are used in one and the same evaluation area, the electrical evaluation powers shall be superimposed in relation to their numbers.

If no other value is calculated, a maintenance factor WF of 0.67 shall be assumed. This can be increased to 0.80 if lamps with only a slight decrease in luminous flux and a low failure rate are used in luminaires that are frequently cleaned and/or do not easily soil and if these are located in very clean rooms. Where rooms and luminaires are exposed to high amounts of dust, being cleaned only infrequently, and if the lamps used have a pronounced decrease in luminous flux and a high failure rate, the maintenance factor shall be reduced to a value up to 0.50.

Table A.4: Utilization factors η_R as a function of the illumination type and the room index

Illumination type	Relative luminous flux φ_u into the lower half-space of the luminaire	Utilization factor η_R									
		Room index k									
		0,6	0,8	1	1,25	1,5	2	2,5	3	4	5
Direct	$\geq 0,7$	0,48	0,59	0,67	0,76	0,82	0,89	0,94	0,98	1,02	1,05
Direct/indirect	$0,1 \leq \varphi_u < 0,7$	0,23	0,30	0,36	0,43	0,48	0,56	0,62	0,67	0,73	0,77
Indirect	$< 0,1$	0,17	0,23	0,29	0,36	0,41	0,48	0,53	0,57	0,62	0,65

NOTE Intermediate values can be obtained by interpolation of the room index values.

Annex B: Rating the energy impact of (dynamic) sunshading systems

In its current version, CEN standard EN 15193 covers daylight supply in “Annex C: Determination of the daylight dependency factor $F_{D,n}$ ”. There, the dependency factor $F_{D,n}$ is determined as a function of the daylight supply factor $F_{D,S,n}$ and the daylight dependent artificial lighting control factor $F_{D,C,n}$.

Daylight supply depends on the following main aspects:

- the geometric boundary conditions, covered by the transparency index, the depth index and the obstruction index described in C.3.1.2, A - D
- the impact of the fenestration, depending on specific construction and material characteristics, such as the type of frame and glazing, covered in C.3.1.2, E, but also on all kinds of installed (moveable) sunshading systems, which are not explicitly covered in the current version of the standard

The current clause “E: Daylight factor classification” of the CEN standard’s Annex C.3, which covers fenestration only partly as indicated above should consequently be replaced by the following method of calculating a daylight supply factor including moveable systems. The method introduced below is based on calculation methods developed for existing standards [2, 3, 5, 6]. Instead of gravely extending clause E, the inclusion of an additional chapter “C.3.1.3 Daylight supply factor” is the preferable solution. In both cases, no information will be lost by replacing clause E, as it actually is, in its current version, a part of the total equation introduced below. In this partial method, only the case where the system is not activated or, equivalent, not existent is covered.

Daylight supply factor

The following section describes the characteristics of façades and specifies how daylight supply is determined on the basis of the correlation of the daylight supply of the building area as specified in C.3.1.1 with the façade characteristics. The light passing through façade systems and the associated illumination of the space bounded by them depends on the spatial and temporal distribution of the external luminance conditions in relation to the façade element and the spatial distribution of the light by the façade system (i.e. its optical and control characteristics). From the lighting-engineering aspect, two façade states are to be distinguished for façades with variable solar radiation protection systems and/or glare protection systems:

- solar radiation and/or glare protection system not activated, i.e. the sun is not shining on the façade
- solar radiation and/or glare protection system is activated, i.e. the sun is shining on the façade.

The daylight supply factor $F_{D,S,n}$ shall be determined using the equation below to achieve temporal weighting of the occurrence of two different façade states (i.e. either with activated solar radiation and/or glare protection or with de-activated solar radiation and/or glare protection), dependent on orientation. Protection against solar radiation and/or glare is activated as soon as direct sunlight shines on the façade.

The equation shown below is used to calculate the daylight supply factor $F_{D,S,n}$

$$F_{D,S,n} = \frac{t_{D,S,SNA,n}}{t_{Day}} F_{D,S,SNA,n} + \frac{t_{D,S,SA,n}}{t_{Day}} F_{D,S,SA,n} = t_{rel,D,S,SNA,n} F_{D,S,SNA,n} + t_{rel,D,S,SA,n} F_{D,S,SA,n} \quad (A1)$$

where

$F_{D,S,SNA,n}$ is the daylight supply factor of the evaluation area n at times when the solar radiation and/or glare protection system is not activated, as given in Table B.5 or calculated using equation (A3);

$F_{D,S,SA,n}$ is the daylight supply factor of the evaluation area n at times when the solar radiation and/or glare protection system is activated, as given in Table B.4;

$t_{D,S,SNA,n}$ is the time during which the solar radiation and/or glare protection system is not activated;

$t_{D,S,SA,n}$ is the time during which the solar radiation and/or glare protection system is activated;

$t_{rel,D,S,SNA,n}$ is the relative portion of the total operating time during which the solar radiation and/or glare protection system is not activated (see Table B.1);

$t_{rel,D,S,SA,n}$ is the relative portion of the total operating time during which the solar radiation and/or glare protection system is activated (see Table B.1);

Relative times, shading activated, shading not activated for vertical façades

Table B.1: Relative times $t_{rel,D,S,SNA,n}$ and $t_{rel,D,S,SA,n}$ for activated and de-activated solar radiation and/or glare protection systems, as a function of the façade orientation

Relative time	Orientation		
	South	East/West	North
$t_{rel,D,S,SNA,n}$ solar radiation and/or glare protection system not activated	0,67	0,8	1
$t_{rel,D,S,SA,n}$ solar radiation and/or glare protection system activated	0,33	0,2	0

If the obstruction index I_o of a shaded façade is less than 0.5, then the relative times $t_{rel,D,S,SNA,n}$ and $t_{rel,D,S,SA,n}$ for a north-facing façade should be used. Depending on the operating times of the area being evaluated, even north-facing façades may receive direct sunlight for limited periods. However, for simplified calculations $t_{rel,D,S,SNA,n}$ is assumed to be 0, but this shall not give reason to assume that glare protection for north-facing façades is unnecessary. Such protection may be necessary due to individual types of usage.

Determination of the daylight availability factor $F_{D,S,SNA,n}$ for vertical façades

The following equation is used to calculate an approximate value of the effective transmittance for periods during which the solar and/or glare protection system is not activated:

$$\tau_{eff,SNA,j} = \tau_{D65,SNA} \cdot k_1 \cdot k_2 \cdot k_3 \quad (A2)$$

where

$\tau_{D65,SNA}$ is the transmittance of the façade glazing for vertical light incidence;

k_1 is the reduction factor for frames and structural divisions

- k_2 is the reduction factor for pollution of the glazing;
- k_3 is the reduction factor for non-vertical light incidence on the façade glazing (usually 0.85 is considered to be adequate).

If the reduction factor k_1 for frames and structural divisions is not known, it must be assumed to be 0.7.

Comment:

Standard values of the pollution reduction factor need to be provided. In most standard cases $k_2 = 0.8$ but for self cleaning glazing it may be higher than 1. For more accurate information on various reduction factors to account for the effect of pollution from a lighting aspect, it is suggested to refer to respective standards, e.g. DIN 5034-3.

If the transparent or translucent façade element to be evaluated comprises different τ components, the effective transmittance must be weighted according to the relative proportion of the areas of the respective components. When determining the obstruction index, the effect of the outer glazing of glazed double façades must be calculated separately. Table B.2 shows typical values of the transmittance $\tau_{D65,SNA}$ for visible light.

Table B.2: Typical values of the transmittance $\tau_{D65,SNA}$ of transparent and translucent building components

Type	U	g_{\perp}	τ_e	$\tau_{D65,SNA}$
Single glazing	5.8	0.87	0.85	0.90
Double glazing	2.9	0.78	0.73	0.82
Triple glazing	2.0	0.70	0.63	0.75
Low-e glazing, double glazed	1.7	0.72	0.60	0.74
Double thermal insulation glazing, type 1	1.4	0.67	0.58	0.78
Double thermal insulation glazing, type 2	1.2	0.65	0.54	0.78
Low-e glazing, triple glazed	0.8	0.50	0.39	0.69
Triple thermal insulation glazing	0.6	0.50	0.39	0.69
Double solar protection glazing, type 1	1.3	0.48	0.44	0.59
Double solar protection glazing, type 2	1.2	0.37	0.34	0.67
Double solar protection glazing, type 3	1.2	0.25	0.21	0.40

The daylight supply factor $F_{D,S,SNA,n}$ is a function of the daylight availability, the maintained illuminance \bar{E}_m , the effective transmittance of the façade $\tau_{\text{eff},SNA,n}$ with de-activated solar and/or glare protection system and of the façade orientation. Estimated values can be taken from Table B.5. For maintained illuminances \bar{E}_m of less than 300 lx, the $F_{D,S,SNA,n}$ values for $\bar{E}_m = 300$ lx should be used. Correspondingly, for maintained illuminances \bar{E}_m of more than 750 lx, the $F_{D,S,SNA,n}$ values for $\bar{E}_m = 750$ lx should be used.

The following equation can be used to calculate the daylight availability factor as a function of the daylight factor D_{RB} :

$$F_{D,S,SNA,n} = a_1 \left[\frac{2}{1 + e^{-1,5 \cdot D_{RB} \cdot \tau_{\text{eff},SNA,j} \cdot a_3}} - 1 \right] + a_2 \left[\frac{2}{1 + e^{-0,5 \cdot D_{RB} \cdot \tau_{\text{eff},SNA,j} \cdot a_3}} - 1 \right] \quad (\text{A3})$$

The function parameters a_1 and a_2 which depend on location, climate, façade orientation and the maintained illuminance \bar{E}_m can be taken from Table B.3 and Table B.4, where these values are exemplified for Frankfurt, Germany.

Comment:

The Tables B.3 and B.4 as well as Figure B.1 provide the exemplary parametrization for German conditions (location Frankfurt). Respective values should be provided for representative places throughout Europe.

Table B.3: Parameters a_1 and a_2 to be used in equation (A2), as a function of the maintained illuminance \bar{E}_m

Parameter	Maintained illuminance \bar{E}_m		
	300 lx	500 lx	750 lx
a_1	0.89	0.58	0.26
a_2	0.10	0.40	0.70

Values of the function parameter a_3 which accounts for the façade orientation are shown in Table B.4.

Table B.4: Parameter a_3 to be used in equation (A2) to account for the façade orientation

Parameter	Orientation		
	South	East/West	North
a_3	1	0.85	0.75

For maintained illuminances \bar{E}_m of less than 300 lx, daylight availability factor $F_{D,S,SNA,n}$ values for $\bar{E}_m = 300$ lx should be used and for maintained illuminances \bar{E}_m of more than 750 lx, the $F_{D,S,SNA,n}$ values for $\bar{E}_m = 750$ lx should be used.

Table B.5: Daylight availability factor $F_{D,S,SNA,n}$ as a function of the effective transmittance of the façade, the daylight availability class, the maintained illuminance and the façade orientation. The table exemplarily shows the respective values for Frankfurt, Germany.

$\tau_{\text{eff,SNA}}$ %	Daylight availability factor $F_{D,S,SNA,n}$								
	(a) South								
	Poor ^a			Average ^a			Good		
	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
<10	0	0	0	0	0	0	0	0	0
10	0.2	0.16	0.11	0.33	0.26	0.18	0.5	0.39	0.28
20	0.39	0.30	0.21	0.59	0.47	0.34	0.78	0.64	0.48
30	0.55	0.43	0.31	0.76	0.61	0.46	0.90	0.76	0.62
40	0.67	0.53	0.39	0.85	0.71	0.56	0.94	0.84	0.72
50	0.76	0.61	0.46	0.90	0.78	0.64	0.96	0.88	0.79
60	0.82	0.68	0.52	0.93	0.82	0.70	0.97	0.91	0.84
70	0.87	0.72	0.58	0.95	0.86	0.75	0.98	0.93	0.88
80	0.90	0.76	0.62	0.96	0.88	0.79	0.98	0.95	0.91
$\tau_{\text{eff,SNA}}$ %	(b) East/West								
	Poor ^a			Average ^a			Good ^a		
	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
	<10	0	0	0	0	0	0	0	0
10	0.17	0.14	0.09	0.29	0.22	0.15	0.44	0.34	0.24
20	0.34	0.26	0.18	0.52	0.41	0.29	0.72	0.58	0.43
30	0.48	0.38	0.27	0.69	0.55	0.41	0.86	0.72	0.57
40	0.60	0.47	0.34	0.80	0.66	0.50	0.92	0.80	0.67
50	0.69	0.55	0.41	0.87	0.73	0.58	0.95	0.85	0.74
60	0.76	0.62	0.47	0.91	0.78	0.64	0.96	0.89	0.80
70	0.82	0.67	0.52	0.93	0.82	0.70	0.97	0.91	0.84
80	0.86	0.72	0.57	0.95	0.85	0.74	0.98	0.93	0.87

Table B.5 (continued)

$\tau_{\text{eff,SNA}}$ %	Daylight availability factor $F_{D,S,SNA,n}$								
	(c) North								
	Poor ^a			Average ^a			Good ^a		
	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
<10	0	0	0	0	0	0	0	0	0
10	0.15	0.12	0.08	0.25	0.20	0.14	0.39	0.30	0.21
20	0.30	0.23	0.16	0.47	0.37	0.26	0.67	0.53	0.39
30	0.43	0.34	0.24	0.64	0.51	0.37	0.82	0.68	0.52
40	0.55	0.43	0.31	0.76	0.61	0.46	0.90	0.76	0.62
50	0.64	0.51	0.37	0.83	0.69	0.54	0.93	0.82	0.70
60	0.71	0.57	0.43	0.88	0.75	0.60	0.95	0.86	0.76
70	0.77	0.63	0.48	0.91	0.79	0.65	0.96	0.89	0.81
80	0.82	0.68	0.52	0.93	0.82	0.70	0.97	0.91	0.84

^a The following daylight factors $D_{RB,j}$ of the raw carcass opening were used to calculate these values:

- poor: 3 %;
- average: 5 %;
- good: 8 %.

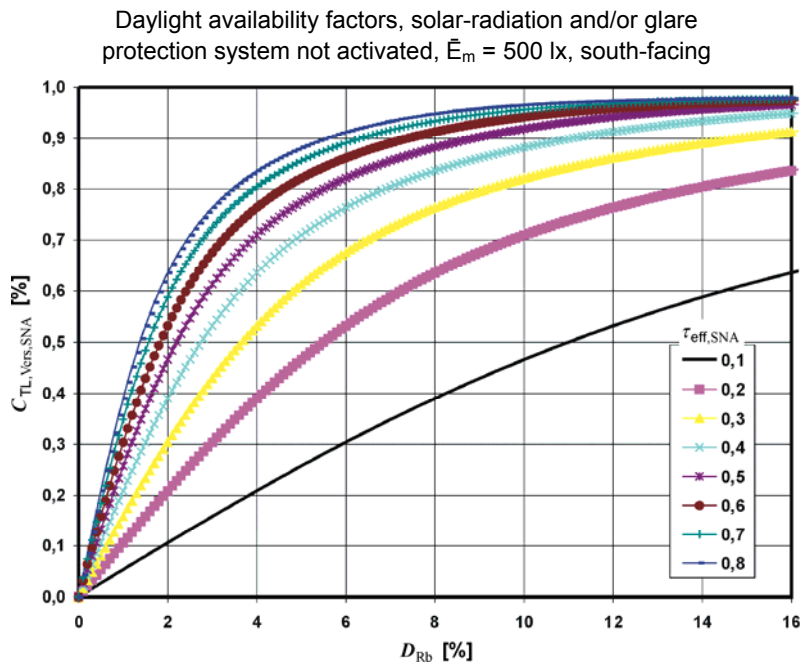


Figure B.1: Example of a set of functions used to determine the daylight availability factor $F_{D,S,SA,n}$ (called $C_{TL,Vers,SNA,j}$ in the figure) as a function of DRB and $\tau_{\text{eff,SNA},n}$ according to equation (A2) for $\bar{E}_m = 500$ lx and a south-facing façade

Determination of $F_{D,S,SA,n}$ for vertical façades (simplified approach)

Façade system solutions with an activated solar and/or glare protection can be classified in a simple manner, specified as follows:

Table B.6: System solutions (values to be applied for the period $t_{rel,D,S,SA,n}$)

System solutions (to be used for the period $t_{rel,D,S,SA,n}$)	
1	Glare protection only: systems which provide glare protection in compliance with the regulations applying to the respective utilization profile, e. g. regulations for computer terminal workplaces. This includes manually operated Venetian blinds.
2	Automatically operated protection against solar radiation and glare: Devices to protect against solar radiation and/or glare and which can be moved in relation to the amount of daylight available. Venetian blinds which are automatically opened slightly after being lowered, so that transmittance is greater than that of the fully-closed blinds.
3	Light-guiding systems
4	No protection against solar radiation and shades. NOTE Only applicable for areas being evaluated to which no special regulations or provisions such as the regulations for computer terminal workplaces apply.

Light-guiding system solutions (row 3 of Table B.6) can be assumed to include solutions of type 1 with additional light-guiding functions:

- *Venetian blinds in cut-off operating mode:* In the so-called “cut-off” mode, the louvres of the blinds are directed in relation to the incident sunlight in such a way that direct sunlight is just prevented from passing through, but diffuse daylight can enter. Furthermore, these systems generally permit visual contact to the surroundings for a large part of the operating time. Appropriate control systems which move the louvres in relation to the solar radiation profile angle must be installed. The sun profile angle is the projection of the altitude angle of the sun onto a vertical plane which is perpendicular to the plane of the façade surface.
- *Light-guiding glass:* Façade systems using glass components which transmit at least 30% of the incident sunlight into the upper quarter of the space when the vertical sunlight is received from an altitude of less than 35°. As a general rule, not more than 1/3 of the transparent façade openings should be equipped with such systems in order to prevent overheating of the respective space. Light-guiding glass must be combined with other solar radiation protection and/or glare protection systems installed in the lower section of the façade area. However, no solar and/or glare protection devices may be installed in front of the light-guiding components described below.
- *Daylight-guiding external Venetian blinds:* These have diffuse surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind must not be higher than 1/3 and not lower than 1/4 of the total blind length and the system must be equipped with control devices.
- *Daylight-guiding internal Venetian blinds between glazing layers or in the air space of glazed double façades:* These have highly reflective or mirror-finished surfaces and the louvres of the upper and lower sections of the blinds are at different angles. The upper section of the blind must not be higher than 1/3 and not lower than 1/4 of the total blind length and the system must be equipped with control devices.

However, no solar and/or glare protection devices may be installed in front of the light-guiding components listed in Table B.6.

Annex C: Daylight-responsive control systems

In its current version, the CEN-standard's Annex C, clause 4 "Daylight dependent artificial lighting control $F_{D,C}$ " covers the effect of control systems only in a very simplified manner. The following suggestion to cover daylight-responsive control systems in more detail and to provide additional explanations is meant to replace the current clause C.4 of EN 15193. The method introduced below is based on calculation methods developed for existing standards [2, 5].

Daylight-responsive control systems

The effects taken into consideration here relate to the characteristics of the artificial lighting controls deployed to supplement the available daylight in order to achieve the required illuminance. Control systems which control or regulate the transmission of light through the façades are not discussed here.

The correction factor $F_{D,C,n}$ for daylight-responsive control systems is a function of:

- a) the type of control involved
- b) the daylight supply classification of the zone
- c) the maintained illuminance \bar{E}_m

Artificial lighting control systems are distinguished according to whether they are:

- controlled manually or
- controlled automatically in order to adjust the artificial light intensity according to daylight supply

An additional distinction is made between the following systems:

- i) Systems which are daylight-responsive ("on/off") and turn off the artificial lighting when the maintained illuminance is achieved by daylight at the point where the luminance is measured. The artificial lighting is switched on again automatically when the maintained illuminance is no longer achieved by daylight.
- ii) Systems which are daylight-responsive and turn on or off in stages ("on/off in stages"). The artificial lighting is switched off in stages until the maintained illuminance is achieved by daylight at the point where the luminance is measured. The artificial lighting is switched on again automatically in stages when the maintained illuminance is no longer achieved by daylight.
- iii) Systems which are daylight-responsive and turn off the artificial lighting ("daylight-responsive off"). The artificial lighting is switched off when the maintained illuminance is achieved by daylight at the point where the luminance is measured. The artificial lighting has to be turned on again manually.
- iv) Systems which are daylight-responsive and dim the artificial lighting without switching it off, then turn on again ("dimmed, stand-by losses, switch-on"). The artificial lighting is dimmed to the lowest level during usage periods (periods with adequate daylight) without being switched off (i.e. it uses electrical power ("stand-by losses")). The artificial lighting system is turned on again automatically.
- v) Systems which are daylight-responsive, and dim the artificial lighting. It is switched off and turned on again ("dimmed, no stand-by losses, switch-on"). The artificial lighting is dimmed to

the lowest level during usage periods (periods with adequate daylight) and switched off (i.e. no electrical power is used). The artificial lighting system is turned on again automatically.

- vi) Systems which are daylight-responsive and dim the artificial lighting but do not switch it off or turn it on again (“dimmed, stand-by losses, no switch-on”). As system (iv), except that the artificial lighting system is not turned on again automatically.
- vii) Systems which are daylight-responsive and dim and switch off the artificial lighting (“dimmed, no stand-by losses, no switch-on”). As system (vi), except that the artificial lighting system is not turned on again automatically.

The types of control can be operated as stand-alone systems or integrated in installation bus systems or building management systems.

Correction factors $F_{D,C,n}$ are given in Table C.1.

Table C.1: Correction factor $F_{D,C,n}$ to account for the effect of daylight-responsive control systems in a zone n, as a function of the maintained illuminance \bar{E}_m and the daylight supply classification

Type of control			$F_{D,C,n}$ as a function of daylight availability								
			Poor			Average			Good		
			300 lx	500 lx	750 lx	300 lx	500 lx	750 lx	300 lx	500 lx	750 lx
Manual			0,33	0,30	0,27	0,38	0,35	0,32	0,43	0,40	0,37
Automatic	Stand-alone	No total switch-off	0,65	0,70	0,73	0,70	0,73	0,75	0,73	0,75	0,76
		Total switch-off	0,71	0,74	0,76	0,77	0,78	0,79	0,81	0,81	0,81
	Bus systems		0,76	0,81	0,83	0,83	0,85	0,86	0,87	0,87	0,87

NOTE: The values given are taken from an ISO-draft and may be subject to change due to further investigations!

Generally speaking, “on/off” systems (i) are not accepted by users and are deactivated after a short period of time. They shall be treated in the same way as the manual type of control. However, switching the artificial lighting on and off in stages (ii) may be particularly suitable for large interior spaces such as those in factory buildings, for example. Switching the artificial lighting in such spaces on and off in stages shall be treated in the same way as a dimmed system without total switch-off (iv). Systems which are daylight-responsive and turn off the artificial lighting shall also be treated in the same way as dimmed systems without total switch-off (iv). It has been shown in practice that dimmed systems (vi) and (vii), that are not automatically switched on again when the maintained illuminance is no longer reached, are to be evaluated more favourably than systems (iv) and (v) which automatically adjust the artificial lighting back to the prescribed maintained illuminance. For systems (vi) and (vii), the correction factor $F_{D,C,n}$ can be increased by weighting the associated systems with switch-on (iv) and (v) with a factor of 1.1.

Annex D: Benchmark values

In Annex F of the CEN standard's current version about lighting, EN 15193, benchmark values for different types of buildings, such as offices, hotels or restaurants are given. Compared to values derived within different studies based on real installations and research projects, these values appear to be quite high. Consequently it is crucial to rediscuss these values.

In the following, as an example for the studies mentioned above, results of a French study of the year 2005 [7] are related to the standard's benchmark values concerning offices. There, a power density load of 15 W/m^2 is rated low quality, whereas high quality requires 25 W/m^2 . The aim of the study was to find lighting solutions using less than $12,5 \text{ W/m}^2$ (as recommended by the French thermal regulations in 2005 and as indicated by the red line in figure D.1), which are positively appreciated and found comfortable by users. Out of the 26 lighting solutions tested in offices in the Lyon area over a period of 6 months, 10 lighting solutions with a power density of less than 15 W/m^2 were rated high or excellent quality and only 7 were considered to be unsatisfactory.

Especially when keeping in mind that the study is already 5 years old and that the development of high-quality and low-energy lighting solutions has been further advanced, the study's results clearly indicate that the standard's benchmark values are too high.

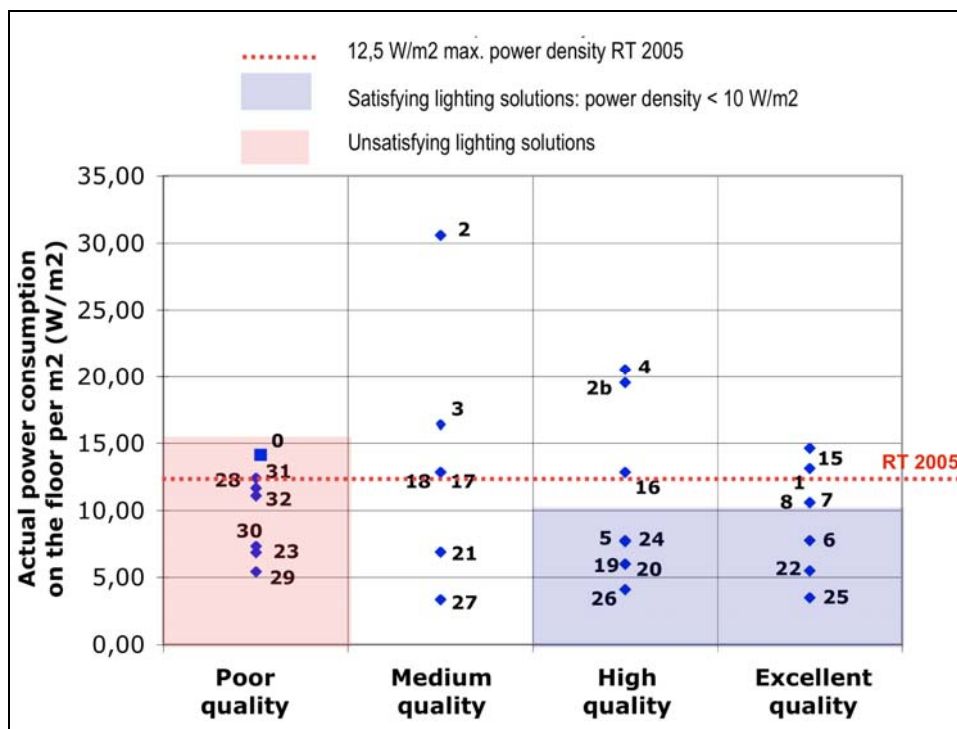


Figure D.1 Diagram presenting the results of a French study [7], showing that most lighting solutions with a power density below 15 W/m^2 are of good quality

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