Computer Aided Calculation of Lighting Energy Consumption for Energy Certification of Buildings

Dionyz GASPAROVSKY, Peter JANIGA

Slovak University of Technology, FEE&IT, Ilkovicova 3, 812 19 Bratislava, Slovakia

1. Introduction

European Parliament and the Council adopted the Directive on Energy Performance of Buildings 2002/91/EC on December 16, 2002. Member countries was obliged to implement this important directive into national legislation not later than January 4, 2006. National Parliament of the Slovak Republic fulfiled its obligation by release of the Act No. 555/2005 on Energy Performance of Buildings, prepared by the Ministry of Construction and Regional Development of SR, under tight collaboration with experts responsible for individual energy systems concerned (1. thermal protection, 2. DHW/heating, 3. air conditioning, 4. electrical installations and built-in lighting systems). Requirements for lighting and issues relevant to lighting have been prepared by authors of this paper. The Act 555/2005, valid since January 1, 2006, actually came in force this year – since 1st January 2008. Basic methodological principles, having force of legislation, are given by the Ordinance No. 625/2006. Similar legislative documents are adopted throughout whole Europe.

It is necessary to point out that the directive mentioned above can be seen as one element of the chain of documents oriented towards energy savings and climate protection, with focus to reduce greenhouse gases and to fulfil Kyoto criteria as the final effect. Following these aims, main goal of the directive is to improve the energy efficiency of buildings. Four main areas have been identified, where lighting systems play an important role – as in lighting there is a huge energy saving potential expected. While other sub-systems concentrate mainly on losses, lighting is a source of saving potential due to very fast technological development.

Based upon legislative documents, which give an overall framework, a set of technical standards have been also ellaborated, translated, processed and released. For the field of lighting, undoubtly the most important standard is: EN 15 193:2007 Energy performance of buildings — Energy requirements for lighting. This standard was put into usage in the territory of Slovak Republic as STN EN 15 193 in April 2008, interesting to say, 3 months

after energy certification of buildings was launched from 1st of January. Delay is caused by ellaboration of this standard on EN level.

Energy certification is compulsory for these building categories: offices and administrative buildings, education buildings, hospitals, hotels, restaurants, sports facilities, wholesale and retail services and manufacturing factories. Energy certification process ends with graphical interpretation of results in a form of an energy label (see Fig.1).

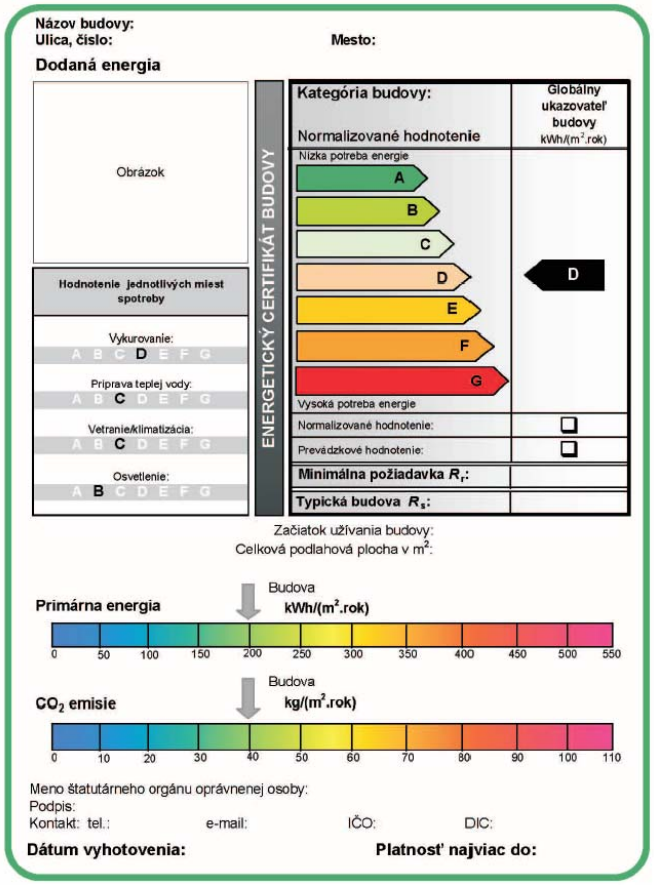

Fig. 1 Energy label sample for a building

2. Methodological background

The European Standard EN 15 193 was devised to establish conventions and procedures for the estimation of energy requirements of lighting in buildings, and to give a methodology for a numeric indicator of energy performance of buildings used for certification purposes.. It also provides guidance on the establishment of notional limits for lighting energy derived from reference schemes.

The standard can be used for existing buildings and for the design of new or renovated buildings. It also provides reference schemes to base the targets for energy allocated for lighting usage and also provides a methodology for the calculation of instantaneous lighting energy use for the estimation of the total energy performance of the building.

Having the correct lighting standard in buildings is of paramount importance and the convention and procedures assume that the designed and installed lighting scheme conforms to good lighting practices. For new installations the design should be in accordance with EN 12464-1. However, in Slovak Republic this requirement is rarely fulfiled what causes serious problems in certification process. It seems that a methodology is needed to assess lighting systems not conforming to good lighting practice, including older lighting installations.

The standard offers three methods for estimation of lighting energy consumption:

1. Quick method: estimation of annual lighting energy consumption for typical building types, using standard values of parameters influencing to diminishing the installed lighting power. Quick method is intended for lighting design, not certification as many misunderstood.

2. Comprehensive method: the comprehensive method, intended for certification, allows for a more accurate determination of the lighting energy estimations for different periods (e.g. annual or monthly). This method may be used for any periods and for any locations provided that the full estimation of occupancy and daylight availability is predicted.

3. Lighting energy metering: this auxiliary method can bring the most accurate information on lighting energy consumption. However, this method is not supported by legislation, meets serious technical complications and requires long-term monitoring (one year minimum). So it can be used for continuous non-authorized lighting energy monitoring in order to collect information and propose energy rationalisation.

Energy consumption related to building area is defined as a Lighting Energy Numeric Indicator (LENI), which can be established using the following equation:

$$LENI = \frac{W}{A} \quad [\text{kWh}/(\text{m}^2.\text{year})] \qquad (1)$$

where

W is the total annual energy used for lighting [kWh/year]

A is the total useful floor area of the building [m2]

The total annual energy used for lighting consist of two parts:

$$W = W_L + W_P \quad \text{[kWh]} \tag{2}$$

where the lighting energy required to fulfil the illumination function and purpose in the building (W_L) shall be established using the following equation:

$$W_L = P_n F_C F_O \left(t_D F_D + t_N \right) \text{ [kWh]} \tag{3}$$

and estimate of the parasitic energy (W_P) required to provide charging energy for emergency lighting and for standby energy for lighting controls in the building shall be established using the following equation:

$$W_P = P_{PC} \left(t_Y - t_D - t_N \right) + P_{em} t_{em} \quad \text{[kWh]} \tag{4}$$

where

P_n installed power of the lighting system

P_{PC} total installed parasitic power of the controls

P_{em} total installed charging power of the emergency lighting luminaires

F_D daylight dependency factor

F_O occupancy dependency factor

F_C constant illuminance factor

t_D daylight time usage

t_N non-daylight time usage

t_Y standard year time

t_{em} charding time of emergency luminaires

3. Improvements of the standard methodology

Methodology published in the standard has still many gaps that gives unnecessary freedom to certificants and/or do not provide certificants sufficient guidance how to calculate several parameters or to assess several situations.

3. 1. Proposal for calculation of the “luminous energy consumption”

LENI can be used for comparison of lighting systems efficiency in buildings with similar usage. LENI is included into total energy indicator taking into account all relevant energy systems in buildings. For comparison of different kind of buildings, LENI is unsuitable and insufficient. For this reason, requirements for minimum LENI (for new or reconstructed buildings) as well as definition of energy classes based upon value of LENI, stated in legislative documents, is given in a form of table. Thus, depending on building category, energy classes range on different LENI values.

An additional parameter – „luminous energy consumption“, is useful for assessment of real lighting energy demand because it takes into account illuminance levels prescribed by relevant standards (namely EN 12464-1, for instance) for individual rooms types. If not considering this fact, it is hard to compare two buildings of the same category (e.g. administrative buildings) with different structure of rooms. It is clear, for example, that smaller buildings need to provide the same infrastructure and will have more portion of social rooms, corridors and storage rooms against office rooms, which play the leading role. In big buildings with large open-plan offices this portion will be different and so the lighting energy demand/consumption. It is more fair to relate the installed power in particular rooms not only per meter sqare but also per lux, what is nothing new but a common lighting practice.

Therefore, unlike for other sub-systems where it is not possible, lighting can be asessed and compared also between buildings of different usage category, if establishing a special indicator taking into account lighting requirements in individual building rooms (i.e. 500 lx for offices, 100 lx for corridors etc.). This indicator, named “luminous energy consumption” is defined by the slovak national law upon proposal of Gasparovsky[1]. It can be calculated as follows:

$$\eta_E = \frac{W}{\sum E_m.A} \quad [\text{kWh/(m}^2\text{.year.lx)}] \qquad (5)$$

where

E_m normative maintained illuminance in a room (lx)

A useful area of a room (m^2)

Maintained illuminance E_m shall be taken from technical documentation (lighting design project) and if not available, it shoud be determined according to EN 12 464-1 as a new installation.

Note: Luminous energy consumption is meaningless for the quick method. Calculation must be performed room per room, as usual for energy certification using the comprehensive method.

3.2. Derivation of procedures for calculation of the daylight time usage and non-daylight time usage

Comprehensive method requires determination of daylight and non-daylight time usage. Though first draft of the standard prEN 15193-1[4] (division to parts was later cancelled) integrated this procedure within the method, but preliminary composed equations and formulas were errorneous (mainly due to big lack of time) and unfunctional, so in final version of this standard the procedure is excluded. As a result, authorized certificants do not have any guidline how to perform the calculation. To help, slovak national methodology (term officially adpoted by the EC) introduces a method as proposed by Gasparovsky[5]. This method is partially inspired by original procedure of prEN 15 193-1 and created utilizing experience in the field of solar energy engineering, involving various empirical formulas. On the other hand it is necessary to point out that if there is no procedure published as a normative document, certificant may choose any suitable method with a greater freedom. Anyhow, guidline is a need for majority of certificants.

Determination of daylight and non-daylight time usage is performed on monthly base. It means, that all the following calculations (referred as a “procedure”) must be performed for each month and summed up at the end.

Input data are as follows:

- t_{start} - starting operation time of a building (“from“)
- t_{end} - starting operation time of a building (“to“)
- γ_s (°) - geographical latitude of a building
- λ_s (°) - geographical longitude of a building

Order number for 15th day of a given month “i” (1 to 12) is taken from this set:

J_i = {15, 46, 74, 105, 135, 166, 196, 227, 258, 288, 319, 349}.

Number of days for a given month “i” (1 to 12) is taken from this set:

N_i = {31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31}

Calculation of date angle J'_i (°)

$$J' = J.360°/365 \quad (6)$$

Time equation η_i

$$\eta(J) = 0{,}0072\cos J' - 0{,}0528\cos 2J' - 0{,}0012\cos 3J' - 0{,}1229\sin J' - 0{,}1565\sin 2J' - 0{,}0041\sin 3J' \quad (7)$$

Declination δ_i (°)

$$\delta(J) = 0{,}3948 - 23{,}2559\cos(J'+9{,}1°) - 0{,}3915\cos(2J'+5{,}4°) + 0{,}1764\cos(3J'+26{,}0°) \quad (8)$$

Hour angle ω_i (°)

$$\omega_i = \arccos\left[tg\gamma_S tg\delta\right]$$

Time of sunrise and sunset are calculated by means of these equations:

$$t_{sunrise,i} = \frac{\omega_i}{15°} - \eta(J) - \left(\frac{\lambda_S - 15}{15}\right) \quad (9)$$

$$t_{sunset,i} = \frac{360° - \omega_i}{15} - \eta(J) - \left(\frac{\lambda_S - 15}{15}\right) \quad (10)$$

Operation time before sunrise $t_{bs,i}$ (h) and after sunset $t_{as,i}$ (h) is determined by comparison of time of sunrise/sunset with time of start and end of building operation:

IF: $t_{sunrise,i} > t_{start}$ $t_{bs,i} = t_{sunrise,i} - t_{start}$

IF: $t_{sunrise,i} \leq t_{start}$ $t_{bs,i} = 0$

IF: $t_{end} > t_{sunset,i}$ $t_{as,i} = tend - t_{sunset,i}$

IF: $t_{end} \leq t_{sunset,i}$ $t_{as,i} = 0$

Weekend regime is taken into account via weekend correction factor C_{we} (1):

If building is in operation all the week: $C_{we} = 1$

If workdays include Monday to Saturday: $C_{we} = 6/7$

If only Monday to Friday are workdays: $C_{we} = 5/7$

Daylight time usage $t_{D,i}$ (h/month) and non-daylight time usage tN,i (h/month) for a given month "i" is calculated as follows:

$$t_{D,i} = N_i C_{we} \left[\left(t_{end} - t_{start} \right) - \left(t_{bs,i} + t_{as,i} \right) \right] \quad (11)$$

$$t_{N,i} = N_i C_{we} \left[\left(t_{bs,i} + t_{as,i} \right) \right] \quad (12)$$

Annual daylight time usage t_D (h/year) and non-daylight time usage t_N (h/year) is calculated suming up the monthly values:

$$t_D = \sum_{i=1}^{12} t_{D,i} \quad t_N = \sum_{i=1}^{12} t_{N,i} \quad (13)$$

4. Implementation of the methodology into software calculation tools

Complicateness of methodology do not allow calculation other than by means of computeral tools. Note, that all the procedure must be performed for each individual room. So parallel to the preparation and improvement of the methodology, also supporting calculation tools are being ellaborated. Due to differences between national conditions, mainly country specific software is being created, however, there are rumours that common software is under preparation. Philosophy of these is based on idea of normative methodological core and adjustation of national databases and conditions (like e.g. climatotecchnical data, energy efficiency classification etc.).

Another question is if there should be a common software for all sub-systems or three-four independent programs for experts active in their field. It seems, and first experience give a cleare evidence of that, that independently acting experts have just a little chance to meet using one tool, what is unpractical and time consuming. So independent software are being prepared instead. In Slovak Republic the state of the art follows this philosophy and it is supposed to possibly tie these programs together in future via generally agreed data exchange format (first it just have to be proposed, some R&D work is still needed here).

Authorisation of software is also a matter of decision. The question is, if there should be a body responsible for verification of commercially manufactured software or there will be no guarantee for the software usage. Current decisions made in Slovakia follow the principle of liberal market without authorisation. It means, in fact, that software must be assumed as a tool for certificants, while certificants are fully responsible for they results. It practically means just one – certificants must be provided for all the preliminary results, they need to have an option to watch, check, inspect and modify every single result throughout the calculation procedure. And software have to allow this.

Up to now, for the field of lighting there are some software aids for certificants, made by TYPHOON (2007-2008):

EHB LiteCalc – core calculation tool for energy certification

EHB QuickCalc – a quick method version for designers

EHB PriceCalc – calculation of costs for price offer

EHB LiteForm – a set of table sheet forms for data collection during visual inspection

ENERGETICKÝ CERTIFIKÁT BUDOVY

Názov budovy: Budova THOMSON

Ulica, číslo: Obchodná 15 **Mesto:** Bratislava

Osvetlenie

	Jednotka	Hodnotenie
A		
B		
C		
D		
E		
F		
G		G

Výsledky normalizovaného/prevádzkového hodnotenia	
Potreba energie na osvetlenie kWh/(m^2.rok):	1 070
Požiadavka:	20
Spĺňa požiadavku (áno/nie):	nie

Meno oprávnenej osoby: Meno Priezvisko, Reg. č.: XXX
Obchodné meno: **Sídlo:**
Identifikačné číslo: **Register:** **Č. zápisu:**
Meno zhotoviteľa: **Podpis:**
Meno štatutárneho orgánu oprávnenej osoby:
Podpis štatutárneho orgánu:

Fig. 2 EHB LiteCalc – Energy Label Sheet

EHB LiteCalc (Fig. 2 - 4), actually in version 2 (new version is under preparation) is based upon well known and highly accepted excel format what makes it very easy to use, however, application itself is compiled and encapsulated in an executable file. Due to continuous problems with compilator there are attempts to release a pure excel application in new version.

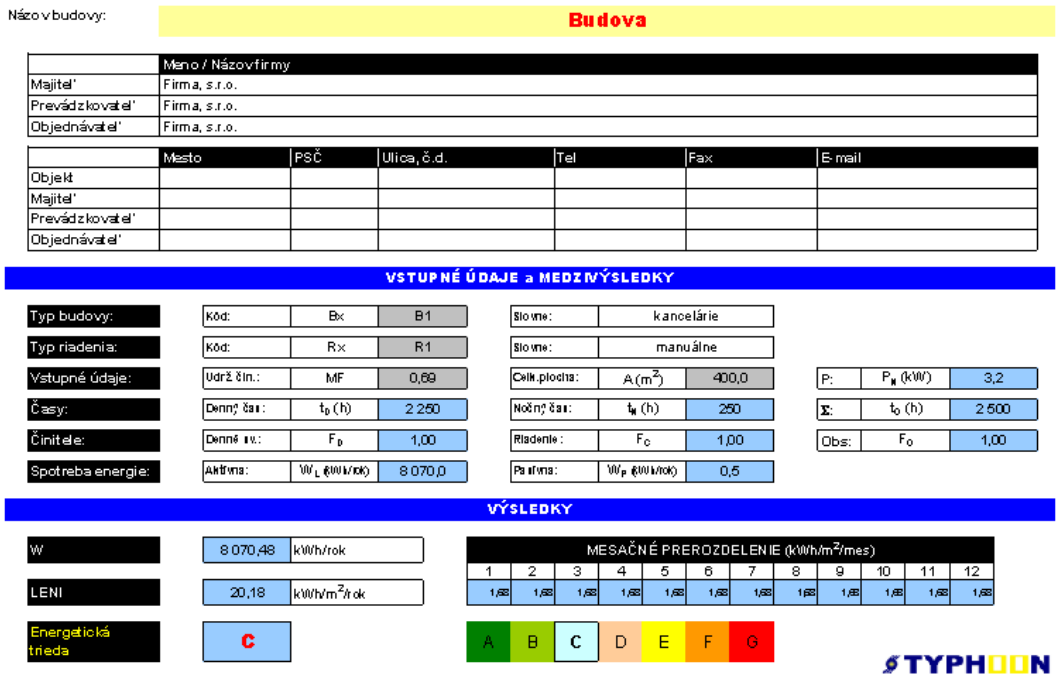

Fig. 3 EHB LiteCalc – Results Sheet

Por	ČM	Názov	SPOTREBA ENERGIE			ČINITELE				
			W	W_L	W_P	F_D	F_O	F_C	F_A	F_{OC}
			kWh/rok	kWh/rok	kWh/rok	-	-	-	-	-
1	121	Kancelária	785,7	785,5	0,1	0,68	1,00	1,00	0,20	1,00
2	122	Kancelária	909,8	909,6	0,1	0,80	1,00	1,00	0,20	1,00
3	123	Rokovacia miestnosť	1 178,5	1 178,3	0,2	0,68	1,00	1,00	0,20	1,00
4	124	WC	40,3	40,3		0,65	1,00	1,00	0,20	1,00
5	125	Chodba	652,5	652,3	0,2	0,76	1,00	1,00	0,20	1,00

Fig. 4 EHB LiteCalc – Output Sheet (fragment)

References

1. Act No. 555/2005 of the National Parliament of Slovak Republic on the Energy Performance of Buildings
2. Ordinance No. 625/2006 of the Ministry of Construction and Regional Development of Slovak Republic
3. Technical standards EN 15 193:2007 and STN EN 15 193:2008

4. Preliminary standard prEN 15 193:2005

5. Slovak National Methodology on Energy Performance of Buildings

6. Software package EHB LiteCalc, EHB QuickCalc, EHB PriceCalc and EHB LiteForm, Typhoon 2008