Energy Performance of Buildings and Lighting: Problems and Solutions

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1. Introduction

Energy performance of the lighting systems is considered in the related European Standard EN 15193 entitled “Energy requirements for the lighting” that specifies the calculation methodology for the evaluation of the amount of energy used for indoor lighting inside the building and provides a numeric indicator for lighting energy requirements used for certification purposes [1]. This standard can be used for existing buildings and for the design of new or renovated buildings. It provides reference schemes to base the targets for energy allocated for lighting usage. This standard also provides guidance on the establishment of national limits for lighting energy derived from reference schemes.

Although there are many considerations on lighting systems and buildings properties related to lighting in the standard, some problems occur during the implementation that are necessary to be solved in order to make best implementation in practice and achieve accurate and comparable results. Slovak Republic developed her national methodology introducing new approaches to some of the relevant problems. Besides, Turkey is on the way of preparing her national methodology recently, which will come in force December 5th, 2009.

In this paper, theoretical background together with calculation methodology itself, problems and challenges those may be appeared during practical applications and possible solutions to the referred problems will be discussed on the basis of Slovak and Turkish conditions.

2. Theoretical Background

With the rapid increase in human population resulting higher energy demands day by day, it has already been reached a critical level of greenhouse gas emissions particularly CO_2. Thus, many studies, actions and implementations have intensively been realized for more than ten years. Since it is a global threat, the Kyoto Protocol which is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC), was adopted in 1997 and entered into force in 2005 with the goal of achieving stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system [2,3].

Since more than 85% of energy [4] is still produced with fossil fuels, it is obvious that the concentrate of CO_2 will be increased. As one of the main objectives is to reduce the CO_2 emissions, it refers to reduce energy consumption which results efficient use of energy together with efficient production. In the scope of this, many countries deal with legislative tasks that are to force to decrease energy consumptions.

In the EU, many Directives referring to KYOTO protocol by the aim of reducing greenhouse gas emissions had already been published such as energy end-use efficiency and services, ecodesign, energy performance of buildings etc. The related directive for this report is EC Directive on Energy Performance of the Buildings, published in 2002, of which the objective is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness [5]. It stated that Member States shall apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of the general framework set out in the Annex. Parts 1 and 2, taking into account standards or norms applied in Member State legislation. It is also stated that this methodology shall be set at national or regional level.

The methodology referred for calculation of energy requirements for lighting systems is CEN Methodology EN 15193 which specifies the calculation methodology and provides a numeric indicator for lighting energy requirements used for certification purposes on the basis of building properties excluding other factors such as occupants' behaviors that are independent from the building properties. Conclusively, the main aim of the standard arises as reducing the energy consumed by lighting systems thus the CO_2 emissions. And it is also stated in the standard that the methodology and format of the presentation of the results would satisfy the requirements of the EC Directive on Energy Performance of Buildings.

In this European Standard, the buildings are classified in the following categories: offices, education buildings, hospitals, hotels, restaurants, sports facilities, wholesale and retail services and manufacturing factories. It also gives advice on techniques for separate metering of the energy used for lighting that will give regular feedback on the effectiveness of the lighting controls. The methodology of energy estimation not only provides values for the numeric indicator but will also provide input for the heating and cooling load impacts on the combined total energy performance of building indicator. Figure 1 gives an overview of the methodology and the flow of the processes involved.

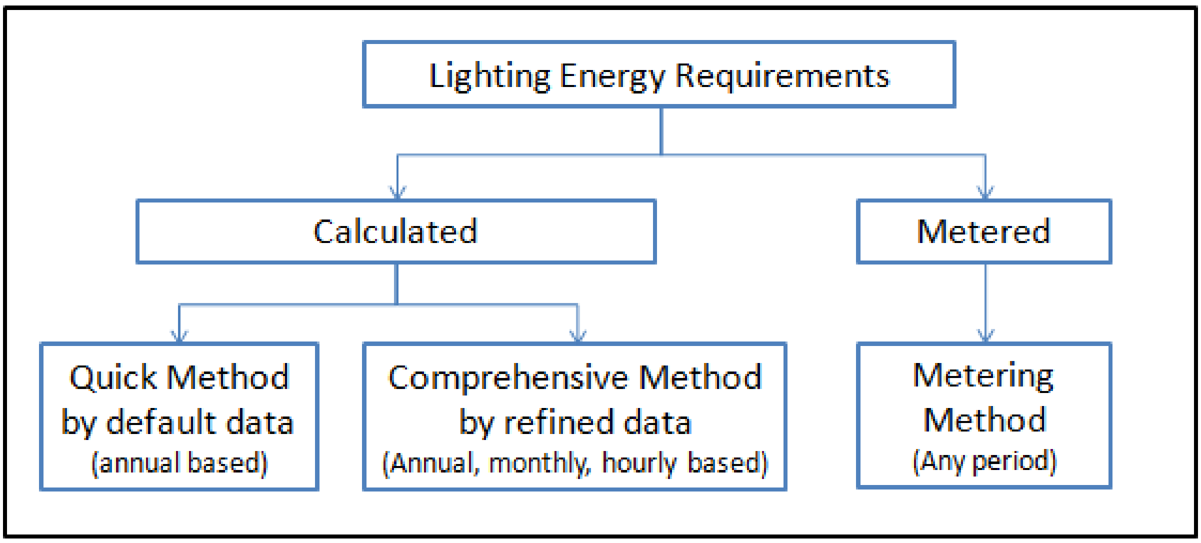

Figure 1. Flow chart illustrating alternative routes to determine energy use (EN 15913)

In some locations outside lighting may be fed with power from the building. This lighting may be used for illumination of the façade, open-air car park lighting, security lighting, garden lighting etc. These lighting systems may consume significant energy and if they are fed from the building, this load will not be included in the total energy required by the lighting systems, namely the Lighting Energy Numeric Indicator (LENI), or into the values used for heating and cooling load estimate.

Additionally, it is referred to some other documents indispensable for the application of this standard as given below:

- EN 1838, Lighting applications — Emergency lighting
- EN 12193, Light and lighting-Sports lighting
- EN 12464-1:2002, Light and lighting-Lighting of work places-Part 1: Indoor work places
- EN 60570, Electrical supply track systems for luminaires (IEC 60570:2003, modified)
- EN 60598 (all parts), Luminaires
- EN 61347 (all parts), Lamp control gear

2. The Calculation Methodology

The standard offers three methods for estimation of lighting energy consumption as shown in Figure 1:

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 and also can be done in a very short time by using default values where there is no sufficient data from a building. Focusing on the total installed power of the lighting systems in the building and using the default values given in the tables with some assumptions will be enough to perform this method. The energy requirement estimation by this method will yield higher LENI values than that are obtained by the more accurate comprehensive method.

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. Unlike the quick method, building data is obtained by entering in every rooms of the building.

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 rationalization.

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

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

where;

W is the total annual energy used for lighting [kWh/year]
A is the total useful floor area of the building [m^2]

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

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

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

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

and estimation of the parasitic energy (W_P) required to provide charging energy for emergency lighting and for standby energy of 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} charging time of emergency luminaires

4. Identified Problems and Recommended Solutions

Since this methodology was prepared in a very short period, this brought some challenges and problems to be solved while applying this methodology in certification processes. As it is seen from the equations (3) and (4), many factors and parameters are taken into account in order to estimate annual energy consumption in a most accurate way. Although this methodology considers many technical details of a lighting system together with the building properties such as daylight availability from the windows and effect of the surroundings of the building, there exist some problems encountered during implementation of this standard which will be considered in the following sections. Those problems should be clearly identified and possible solutions to the referred problems should be clearly stated. Additionally, for smooth and accurate implementation of the standard, there should be an additional legislative document to be prepared for removing these barriers and accomplishing the challenges which will possibly occur during certification process.

4.1. Insufficient Illumination Levels

Having the correct lighting standard in buildings has utmost 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 with respect to EN 12464-1 which defines the required illumination levels on the working planes. Thus, in order to compare buildings among each other, estimated energy consumption of the lighting systems should be determined in all buildings that are assumed to fulfil the lighting criteria particularly the average illumination level. If the average illumination level cannot fulfil the standard, then required energy demand for lighting of that room will be lower than the room that can fulfil it. This situation will mislead the certification process into inconvenient situation that will prevent the comparison possibilities among the buildings. Since EN 15193 methodology estimates the energy for lighting by assuming the required lighting criteria is provided by the lighting systems, there is need of measurements of the illumination levels achieved in room by room that is to check the relevance of the maintained illumination level according to EN 12464-1 for indoor work places and EN 12193 for sports lighting.

As a common approach, the energy consumption values can be normalized to the values that can provide the required illumination levels. For example, the installed power of the lighting system should be multiplied by two when the maintained illuminance is measured as 250 lx in average where it should have been 500 lx. Oppositely, there can be an oversized lighting system providing more illumination levels than required. In those cases, there is no need to consider overloaded lighting systems since it will be accepted as the property of the lighting system. Those considerations will bring an additional parameter to the equation (3) which can be defined as F_{Em} that only be evaluated by the measurements. Then, the equation (3) differs as:

$$W_{Ln} = P_n F_C F_O F_{Em}\left(t_D F_D + t_N\right) \text{ [kWh]} \tag{5}$$

$$F_{Em} = \frac{E_r}{E_m} \quad ; \textit{if } E_m < E_r$$

$$F_{Em} = 1 \quad ; \textit{if } E_m > E_r$$

where;

W_{Ln} Normalized estimated energy required for lighting systems
F_{Em} Maintained illuminance factor
E_r Required illuminance level (EN 12464-1, EN 12193)
E_m Measured illuminance level

Since the lighting criteria have utmost importance in terms of comfort and safety conditions, it should be provided by the lighting systems. From the viewpoint of Slovak National Methodology, the lighting systems that do not fulfil EN 12464-1 and EN 12193 are accepted as unstandardized lighting installations. This problem is solved by a compulsive approach which enforces the buildings to provide the sufficient lighting criteria. From the statistical results obtained from several buildings show that the average illumination levels obtained in the lighting systems that cannot fulfil the lighting criteria is about one third of the required illumination level. Thus, the calculated energy is multiplied by three where the lighting systems cannot provide the required level. This is also considered as giving a penalty to that building because of its improper lighting installations that do not fulfil the standard. As a result of this, lighting energy class will drop to a lower class. For sure, every country should define its own approach to this problem considering its own conditions by deciding how to estimate lighting energy consumption. However, in fact, it is not very practical to measure illumination levels in every room especially in the buildings that have hundreds of rooms with a great amount total area. Thus, measurements should be done methodologically which will be discussed in the next section in order to propose an adequate method for taking into account of illumination levels practically.

4.1.1. Proposed Measurement Methodology

According to Slovak National measurement methodology, the measurements should be done in at least 10% of the rooms. Those rooms are selected by certificant's desire, considering selecting the rooms which can have insufficient lighting systems. After performing measurements, if at least 10% of the selected room cannot fulfil the criteria than total energy required for lighting is multiplied by three. This is such a punitive approach to enforce the building fulfilling the lighting criteria in almost every room.

Certainly, there can be several approaches to reduce the number of the measurements that brings a selective modality to assign the rooms to be measured. For instance, lighting load can be a significant parameter to select a particular ratio of the rooms that are also have longer usage times. As an example, a conference room can have the highest installed power but with lowest usage time. Therefore, the conference room may be ignored for the measurements. Since installed power is mentioned as a selective parameter together with usage time, it can be said that, total installed power of the selected rooms should be at least 50% of the total installed power of the building lighting system. If there are several rooms with lower areas, it can still be unpractical to achieve 50% of total installed power by reducing the room numbers. In those cases, 20% of the rooms can be measured. Of course, the measurements should be performed in all rooms in the cases that it is practical like having considerable room number. (The proposed ratios are draft values. The exact ratios should be determined by experimental and statistical approach in national level.)

Measurements should be done especially on the working planes for achieving the average illumination levels. After the measurements performed in the selected rooms, F_{Em} values should be determined. The average of F_{Em} values that are greater than 1 can be used in the equation given below to calculate the new estimated energy consumption for lighting:

$$W_{Ln} = W_L x \overline{F}_{Em} \qquad (6)$$

where;

W_{Ln} Normalized estimated energy required for lighting systems
W_L Estimated energy consumption with respect to EN 15193
$\overline{F}_{Em}$ Average F_{Em} value of the selected rooms

While proposing F_{Em} approach, the set of rules to be implemented within this methodology can be evaluated as follows:

a) Necessary data to be used in calculation procedure shall be collected from each room.
b) If it is possible, the calculations shall be done in every room, otherwise;
   1. The list of the rooms with required illumination levels in each shall be sorted descending according to installed power.
   2. Rooms shall be selected until representing at least 50% of the total installed power.
   3. Rooms shall be selected considering the usage time; rarely used rooms should be ignored.
   4. If there is enormous number of the rooms, then 2 cases can be considered in order to reduce the number of the measurements:
      i. Duplications: There can be more than one room with same functionality, dimensions and lighting systems therefore, measurements can be performed in one of the rooms.
      ii. Limitations: If first situation is not valid, then 20% of the rooms can be considered to be selected for measurement.
c) If the measurements are performed in all rooms, F_{Em} values shall be calculated for each room; then normalized LENI values for each room shall be calculated by considering those F_{Em} values.
d) In the cases that measurements cannot be performed in each room, $\overline{F}_{Em}$ value shall be calculated for the selected rooms.
e) After calculation of $\overline{F}_{Em}$, it shall be multiplied by LENI calculated by standard procedure of EN 15193 to achieve the normalized LENI.

4.2. Deficiencies in Quick Method

When using the quick method for estimation of the annual lighting energy estimation for typical building types, Equation (2) shall be used. This method is intended for lighting design, not for certification process, by using default values of parameters that are expressed in the equations (3) and (4). Since quick method uses the default values of the factors F_D (daylight dependency factor), F_O (occupancy dependency factor) and F_C (constant illuminance factor) together with daylight time usage (t_D) and non-daylight usage time (t_N) those parameters should be determined for national conditions as it is also stated in EN 15193.

The calculations realized by the default values given in standard will have serious deviations such as falling from lighting energy class A to C or D; according to the comprehensive method even if the national values of those parameters have been defined. Therefore, quick method should be reconsidered and improved by modifying the factors in order to give more accurate estimation for lighting energy demand. As those parameters are examined for quick method, the deterministic parameters arise as F_D and F_O which are derived after many calculations by the data obtained from the room, geographical conditions and the surrounding of the building.

The standard EN 15193 refers to some default values of F_D and F_O factors, given in tables, defining the factors to be used in quick method where the national values are not available. The default values for F_D and F_O factors related to building types defined in the standard given in the Tables 1 and 2, respectively.

Table 1. Impact of daylight for buildings with controls

Building Type	**Control Type**	F_D
Office, sport facilities, manufacturing	Manual	1,0
	Photocell dimming – with daylight sensing	0,9
Restaurant, wholesale and retails	Manual	1,0
Educational buildings, hospitals	Manual	1,0
	Photocell dimming – with daylight sensing	0,8
Note: Assumes that at least 60% of lighting load is under given control.		

Table 2. Impact of occupancy for buildings with controls

Building Type	**Control Type**	F_O
Office, education	Manual	1,0
	Automatic 60% of the connected load	0,9
Retail, anufacture, sports and restaurants	Manual	1,0
Hotels	Manual	0,7
Hospitals	Manual (some automatic control)	0,8
Note: Automatic controls with presence sensing should be allocated at least 1 per room and in large area at least one per 30 m^2.		

As it is seen from the tables, the default values for quick method are so narrowed which make the results of the calculation having great deviations according to the comprehensive method. In order to reduce these big deviations, first of all national values should be derived in the related tables.

As to take attention for deficiency of quick method, F_D factor can be a good example that it is taken as 1 if the lighting control type is referred as manual. That means if there is no daylight sensor, or any control strategy in the related room, F_D factor should be taken 1 even if there is available daylight penetrating in the room. In fact, the users or building management may turn off the lighting systems manually where there is sufficient daylight in the rooms. Thus, F_D factor should be lower than 1 not only in the cases of availability of control systems but also manual control. Certainly the F_D factor should be always lower than 1 for manually controlled lighting systems, however it should be more lower where there exist any type of control strategy. This approach should also contribute for reduction of the deviations mentioned above. According to Slovak National Methodology, several data from the real buildings are obtained and statistically evaluated to constitute the related tables. To define Slovak national values of F_D and F_O factors for typical buildings, data obtained from 23 office buildings were evaluated by means of calculating factors for each room. After related calculations of the factors done in whole building, an average of F_D and F_O factors were determined for each building. Therefore, final F_D and F_O factors were calculated by taking average of those factors from 23 buildings. For the other types of the buildings, those factors are derived from the data of office buildings by some assumptions. Being apart from default values given in the standard, Slovak National Methodology offers more detailed approach by dividing the control systems in nine groups which are shown in Table 3 for determination of default F_D factors. The F_D and F_O factors for the other types of building were also derived from many assumptions, especially by examining the functionalities and properties of the other types of buildings as given in Table 4 and 5, respectively.

Table 3. Lighting control strategies

Lighting control	Group
Manual: ON/OFF without sensors	R1
Manual: ON/OFF with sweeping signal	R2
Motion detector: auto ON + dimming	R3
Motion detector: auto ON + auto OFF	R4
Motion detector: manual ON + dimming	R5
Motion detector: manual ON + auto OFF	R6
Photosensor: manual ON + constant illuminance dimming	R7
Photosensor: daylight control switching or dimming	R8
Central control	R9

Table 4. Slovak national values of daylight factor F_D for quick method

Building category	R1 – R7	R8	R9
Office buildings	0,92	0,85	0,92
Schools and educational buildings	0,92	0,85	0,92
Hospitals	0,92	0,90	0,92
Hotels	0,92	0,92	0,92
Restaurants	0,98	0,98	0,98
Sport facilities	1,00	1,00	1,00
Wholesale and shops	1,00	1,00	1,00

Table 5. Slovak national values of occupancy factor F_O for quick method

Building category	R1 – R2	R3 – R6	R7 – R8	R9
Office buildings	0,7	0,5	0,7	0,6
Schools and educational buildings	0,5	0,4	0,5	0,5
Hospitals	0,9	0,9	0,9	0,9
Hotels	0,8	0,7	0,8	0,8
Restaurants	1,0	1,0	1,0	1,0
Sport facilities	1,0	1,0	1,0	1,0
Wholesale and shops	1,0	1,0	1,0	1,0

Another topic should be considered in this section is about parasitic energy, obtained by equation (4), which is also taken into account for quick method. As it is stated in the standard, in existing buildings where the parasitic energy consumed is not known, this annual energy can be estimated to consist of 1 kWh/m^2.year for emergency lighting and 5 kWh/m^2.year for the automatic lighting controls if used (total is W_P = 6 kWh/m^2.year). This is also a very general approach that should be considered and can be modified with the data obtained from the buildings in time. And for sure, if there is no any emergency lighting or lighting control in the building, W_P should be taken as zero.

4.3. Calculation of Daylight Time (t_D) and Non-Daylight Time (t_N) Usage

Comprehensive method requires determination of annual daylight and non-daylight time usage for calculation of the estimated energy demand of a building. There had been defined a methodology integrated in the first draft of the standard prEN 15193-1, but preliminary composed equations and formulas were erroneous and unfunctional, mainly due to big lack of time, so in final version of this standard the procedure was excluded. As a result, there is no any calculation procedure or guideline for authorized certificants how to determine the daylight time and non-daylight time usage of a building.

In the first draft of the document, standard procedure for calculating the daylight and non-daylight time usage exposed from sunrise and sunset times which are derived by geographical data, latitude and longitude. This procedure refers to monthly calculations where sunrise and sunset times should be exactly determined. Because of the erroneous of the formula, it was canceled however, a new formulization can be proposed for Turkish conditions. This method is inspired by original procedure of prEN 15193-1 and Slovak studies, and created utilizing experience in the field of solar energy engineering, involving various empirical formulas. According to proposed methodology, all the following calculations must be performed for each month and summed up at the end where the input data are as follows:

t_{start} - starting operation time of a building ("from")
t_{end} - ending 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 (°)

$$J' = J.360°/365 \qquad (7)$$

Time equation η_i (h)

$$\eta(J_i) = 3,8196*(0,000075+0,001868\cos J'_i - 0,032077\sin J'_i - 0,014615\cos 2J'_i - 0,040849\sin 2J'_i) \qquad (8)$$

Declination δ_i (°):

$$\delta_i(°) = 0,006918 - 0,399912\cos J'_i + 0,070257\sin J'_i - 0,006758\cos 2J'_i + 0,000907\sin 2J'_i - -0,002697\cos 3J'_i + 0,00148\sin 3J'_i \qquad (9)$$

Hour angle ω_i (°):

$$\omega_i = 180 - \arccos\left[\frac{Cos(90.883)}{Cos\gamma_S \mathrm{Cos}\delta_i} - tg\gamma_S tg\delta_i\right] \qquad (10)$$

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

For i=1,2,3,11 and 12;

$$t_{sunrise,i} = \frac{\omega_i}{15°} - \eta(J_i) - \left(\frac{\lambda_S - 30}{15}\right) \tag{11}$$

$$t_{sunset,i} = \frac{360° - \omega_i}{15} - \eta(J_i) - \left(\frac{\lambda_S - 30}{15}\right) \tag{12}$$

For i= 4,5,6,7,8,9 and 10;

$$t_{sunrise,i} = \frac{\omega_i}{15°} - \eta(J_i) - \left(\frac{\lambda_S - 30}{15}\right) + 1 \tag{13}$$

$$t_{sunset,i} = \frac{360° - \omega_i}{15} - \eta(J_i) - \left(\frac{\lambda_S - 30}{15}\right) + 1 \tag{14}$$

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:$t_{sunrise,i} > t_{start}$ tbs,i = $t_{sunrise,i} - t_{start}$
IF:$t_{sunrise,i} \leq t_{start}$ tbs,i = 0
IF:$t_{end} > t_{sunset,i}$ tas,i = $t_{end} - t_{sunset,i}$
IF:$t_{end} \leq t_{sunset,i}$ tas,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 $t_{N,i}$ (h/month) for a given month “i” is calculated as follows:

$$t_{D,i} = N_i C_{we} \left[\left(t_{end} - t_{start}\right) - \left(t_{bs,i} + t_{as,i}\right) \right] \tag{15}$$

$$t_{N,i} = N_i C_{we} \left[\left(t_{bs,i} + t_{as,i}\right) \right] \tag{16}$$

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

$$t_D = \sum_{i=1}^{12} t_{D,i} \quad , \quad t_N = \sum_{i=1}^{12} t_{N,i} \tag{17}$$

These formulas are adapted to Turkish conditions where some modification had been done to related formulas derived among several formulas especially for determining the time equation and declination angles. Therefore, those formulas can also be evaluated according to the geographical conditions of other countries while applying the most suitable set of formulas. Since there are four main input parameters for calculating daylight and non daylight operation time, geographical inputs latitude and longitude are deterministic data for calculating the sunrise and sunset times. For the rest, it is consisted of regular formulas representing the sum of the values monthly achieved.

4.4. Determination of Building Operating Hours

First of all, it should be noted again that, this standard introduce a methodology relies on the physical properties of the building and the lighting systems, not focused on the users' behaviors, in order to be capable of making comparisons among the same type of the buildings. Since it is aimed to estimate and compare energy need for the lighting systems in the buildings, it should be evaluated under same assumptions and conditions. For example, determination of the default daily thus annual operating hours for the buildings is seriously important because the calculations should be performed on the basis of same assumptions and exceptions both for quick and comprehensive method. Therefore, all certificants should use the same daily operating hours for related building types not use the building's operating time itself; otherwise an office building with longer operating time, such as 24 h a day, will have higher LENI even if it has the most efficient lighting system. Therefore, default annual operating hours for quick method and standard building operating hours for comprehensive method should be determined for achieving most comparable results.

Default values for annual building operating hours are provided in the standard for EU countries considering an average estimation. It is also noted that countries might substitute their national values where necessary. However, quick method already refers to many deficiencies resulting great deviations according to comprehensive method. Therefore, those default values should also be evaluated and modified for reducing the deviation and adapting to national conditions. Despite to excluding the calculation methodology for determining t_D and t_N values from the standard, default annual operating hours for quick method are given as a table offering t_D and t_N values for each building type (Table 6).

Table 6. Default annual operating hours relating to building type (EN 15193)

Building category	t_D	t_N	t_O
Office buildings	2250	250	2500
Schools and educational buildings	1800	200	2000
Hospitals	3000	2000	5000
Hotels	3000	2000	5000
Restaurants	1250	1250	2500
Sport facilities	2000	2000	4000
Wholesale and shops	3000	2000	5000
Manufacturing Factories	2500	1500	4000

Certainly, it can be modified by representing a new table derived from operating hours of the buildings in national level. In order to modify the table given above, national values for start and end time of the typical buildings should be determined. After determination of national daily operation hours, annual operating hours including t_D and t_N values can be calculated by the procedure given in the Section 4.3. Constituting one table that represents whole country considering general building categories will require many data under several assumptions. For this reason, the calculations should be done for many cities which can represent the national conditions and then average of t_D and t_N values can be calculated as national parameters for quick method. Certainly, data will give more accurate calculation results when more cities, distributed homogenously to all regions in the country, are taken into account. However, it can be introduced more than one table for quick method those shall be prepared for different locations or regions if necessary. Certainly, for achieving more accurate results, sub-categorization of the building types is indispensible and should be considered especially when modifying the related tables. The tables should also be updated by the data obtained from the case studies if necessary.

4.5. Reclassification and Subcategorization of the Buildings

As it is stated before, EN 15193 offers a categorization for the building types of which are quite acceptable for many countries however, there can be big differences within some type of the buildings even if they are grouped under same type. For example, schools and educational buildings are covering many types of buildings with different functionalities, properties, activities, consumption behavior and different design etc. such as kindergartens, primary schools, high schools and universities. Apart from the educational buildings, shops can also be subcategorized since there is a rapid increase in shopping centers which has completely different properties than the buildings for wholesale and retail shops. There can be found some other types of buildings which cannot be included into any buildings types such as convention or exhibition centers with high level of occupancy and usage area. Therefore, the classification of the buildings should also be modified where it is also necessary to have subcategories for some building types for the national conditions. Certainly all the related tables and calculations should be modified for the new categorization.

4.6. Other Considerations

Since, the one of the fundamental aim of the directive and related regulations on energy performance of buildings is reducing energy consumption and mitigating CO_2 emissions, subscales should be considered at least to have an idea on possibilities for energy saving opportunities in each system. For example energy class scales for the subsystems of the building like thermal protection, DHW/heating, cooling, electrical installations and built-in lighting systems are necessary for expressing the energy performance of each.

Practically, some other problems occur during certification process. There can be some empty buildings to be rented without lighting systems and building owner can decide not to install any lighting systems and leave it to the tenants. There can also be some buildings or rooms that are inaccessible for example for security issues. In those cases, lighting systems cannot be assessed in certification processes. Besides, some buildings are multifunctional therefore it can be hard to classify them. The experiences gained from the field studies shall contribute to the solution for those problems.

5. Conclusions

Energy certification of buildings is a quite new process began after the publication of the standard EN 15193 in 2007. Some preparation works have been performed in the period between 2005 and 2007, however, most of work is still up to come as problems and imperfections arise from practical experience with certification. This creates a big amount of research works to be performed, in order to improve the methodology and to investigate energy saving potential in buildings, to find out new approaches – all this is a challenge for all who want to add a value to the process leading towards such important aims like limitation of greenhouse effects and climate change.

Especially, insufficient lighting systems are one of the important problems that mislead the certification process, need to be considered in every adoption process. Quick method also arises as another problem because it gives higher LENI values according to the comprehensive method. Therefore the default values for quick method should be modified by national conditions. As the standard excludes the calculation procedure for determination of daylight and non-daylight usage time of the buildings, a national methodology should be offered as a guideline which is a need for majority of certificants. Finally, the buildings should be reclassified and subcategorized if necessary, in order to make accurate classification and comparison.

6. References

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