Lux junior 2009
25. bis 27.9.09 Dörnfeld

Energy Saving Aspects of Lightplanning of Schools and Educational Buildings

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1. Introduction

Requirements for lighting in schools and educational buildings are established in legislative documents and technical standards, mainly in EN 12464-1 which is oriented to illumination of workplaces. In Slovak Republic, kindergartens and schools (on primary level) are managed and financed by municipalities. This leads to situations when allocation of budget for improvement of buildings' infrastructure often do not belong to main priorities or is simply insufficient, moreover, dependant on political decisions. New school buildings are built very rarely, schools occupy older buildings with very obsolete lighting systems. In most of schools age of these systems is more than 20 years and in many cases even much more. Lighting levels are deeply under any standard, maintenance is insufficient or ignored at all, big number of incandescent lamps is just a waste of energy, but also installations with fluorescent lamps are very inefficient. In spite of this fact, modernisation of lighting systems cannot be supported by energy savings, because current illuminance is very low (often less than a fifth of required values) and new systems have to fulfil current standards. This is a serious complication towards decision makers. Therefore, modernisation activities are supported by different approach – hygienic aspects of lighting. No doubt, that lighting has an extraordinary influence on health of pupils – in terms of vision, circadian rhythms, fatigue etc. In recent years, lighting systems re-construction in pre-schools, schools and leisure centers are built on this basis.

2. Major problems of lighting systems

Generally bad condition of lighting in educational buildings in Slovakia is evident at the first sight. Information presented in this paper are, however, supported by tens of audits and passports of lighting systems. Up to now, almost hundred of educational buildings have been audited. Bad condition of lighting is inherited from the past. Buildings have been constructed decades ago and age of lighting systems correspond with the age of buildings. Luminaires mounted before 1990 are usual, though luminaires from 60's are not so rare as well. New or reconstructed systems are mostly exceptional.

“Educational buildings” is a category comprising of different kinds of buildings like pre-school kindergartents (age of children 3 – 6), primary schools (normal or special), primary artistic schools and conservatories, leisure centres etc. (pupils 6 – 14 years old) founded by municipal self-governments. Secondary schools, high schools and training institutions (teenagers 14 – 18) established by self-governing regions also fall into this category. On the other hand, universities and colleges (state or private) covered by separate regulations are excluded due to differences in room structure, way of their usage and energy needs (large lecture halls, laboratories and research centres).

2.1 Lamps

Share of inefficient light sources is extremely high, what is undoubtly the main problem. Surprisingly big number of incandescent lamps are still operated. Schools are typical for unbelievely low efficiency of lighting as a national curiosity. Results of measurements showed that illuminance in class rooms, school offices but also corridors is only 10 to 20 per cent of required level while consumption of electricity is very high. Incandescent lamps are prevalently used in round-shaped surface mounted luminaires or pendant luminaires with diffuse globe, both for 60 W lamp. Such luminaires can be still found in many classrooms, offices with displays and even in kitchens or PC rooms.

Situation with fluorescent lamps is not better. It is common to find 20-years and older tubes in luminaires, mainly T12 types with 40 W power. Until they are not blinking, remain to be operated in spite of their low luminous output. In comparison with modern lamps these are less efficient and thanks to disregarded maintenance the lumen losses are often below 40 % of their initial luminous flux, consuming the same amount of energy. Lamps are replaced only after they stop to lit. In some cases it has been found out that fluorescent lamps have been purchased years ago in big amounts and are still stored for replacements. As shown on fig. 1, these lamps are manufatured by the TESLA Nove Zamky (Slovakia) company in eighties, since the beginning of 90s the factory was bought by OSRAM and Tesla’s activities were terminated.

Figure 1. Old fluorescent lamps T12 Z-40W (left) and T8 Z-36W (right)

Colour of light is for servicemen an unknown term. Installed fluorescent lamps are of different colours side by side, sometimes in the same luminaire. Coolwhite is prevailing in all rooms. Usually, the cheapest tubes with standard luminophor are used. Colour rendering is therefore not satisfactory, for classrooms and schoolrooms Ra > 80 is a minimum requirement. It is a sad curiosity that lamps with light colour 640 (colour rendering index 60, colour temperature 4 000 K) are commonly used also in classrooms for fine arts at primary artistic schools. Let us pose a question: how can pupils work with colours if they see them distorted?

Structure of lamps in primary schools is depicted on graphs (fig. 2 – 4). This structure is composed from results of auditing 18 primary school buildings. Average number of rooms is 168,7 and average total area 5 147 m2 per building. The structure is evaluated for the share of installed number of lamps (n) as well as their total power share □ (ni*Pi) where ni and Pi stand for number and wattage of individual lamp types respectively. Besides structure of lamp kinds, more detailed structure of each type is evaluated as well – fig. 3 shows the share of incandescent lamps of different wattages, similarly fig. 4 shows the structure of linear fluorescent lamps. Structure of other lamp types is evaluate as well (not presented here). Fig. 2 – 4 illustrate the situation for primary schools only, similar analyzes are available also for kindergartens, leisure centres and artistic schools. Primary schools are typical for higher share of fluorescent lamps in comparison with kindergartens, for instance, where incandescent lamps are highly prevailing. Finally, structure of luminaires (taking into account differences of number of lamps per luminaire) is evaluated for all alternatives mentioned above for lamps.

As seen from fig. 2 – 4, one third of installed power is covered by incandescent lamps with highest portion of 60 W types. Assuming minor light sources to be neglectable, the rest of structure is covered by fluorescent lamps with highly preferred 36/40 W types instead of e.g. more efficient 58 W lamps.

2.2 Luminaires

Requirements for construction and fabrication of luminaires are defined in the EN 60598 group of standards. Old luminaire types do not conform these requirements. Perhaps the biggest problem is an inadequate choice of luminaire type for particular applications. Most of luminaires, both for incandescent bulbs or fluorescent tubes, are equipped with a white diffuser. This solution provides highly uniform illumination but absence of directional light after certain time leads to uninspiring monotonous environment and visual fatigue. And all we know that it is not easy to attract and keep a constant attention of pupils during the educational process. Situation in computer rooms (fig. 11) or offices is yet more critical because diffuse light can cause glare by reflection of light on monitors. Requirements for illumination of DSE workplaces are fully ignored in such cases.

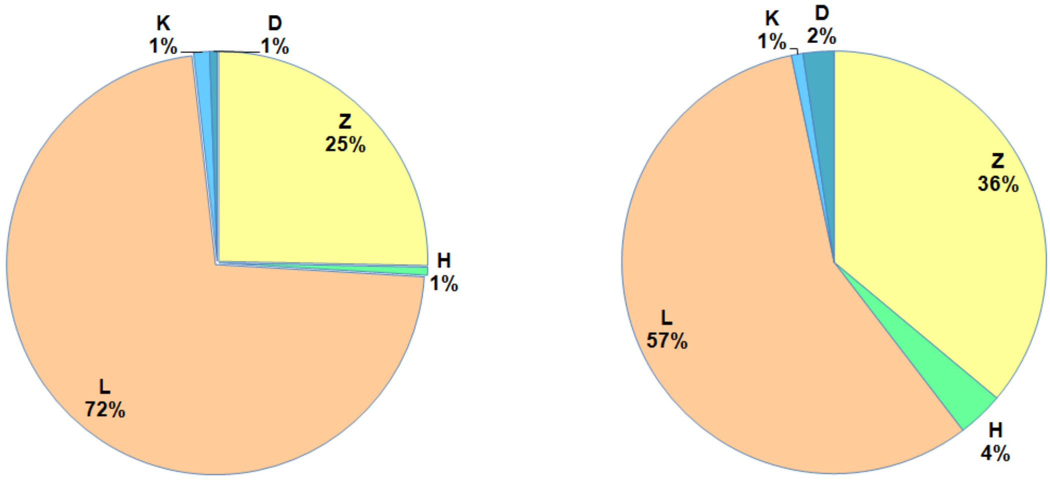


Figure 2. Lamp structure in primary schools – number share (left) and power share (right)

Legend: Z = Incandescent lamps, H = halogen lamps, L = Linear fluorescent lamps, K = Compact fluorescent lamps, D = Discharge lamps

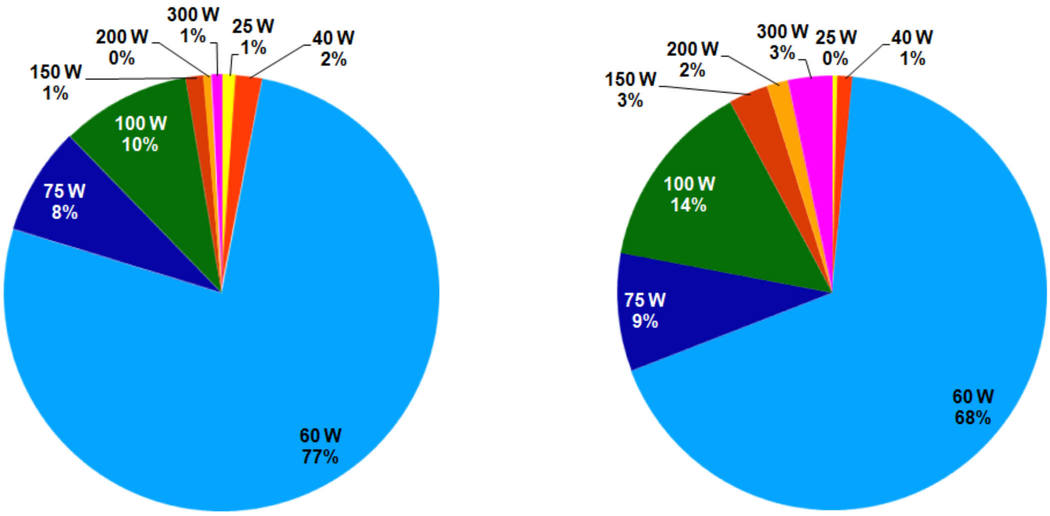
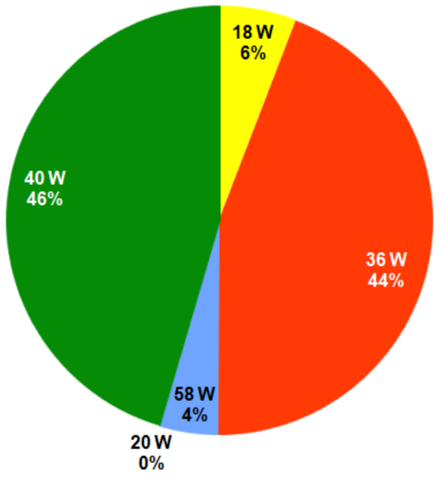


Figure 3. Structure of incandescent lamps of different wattage in primary schools – number share (left) and power share (right)



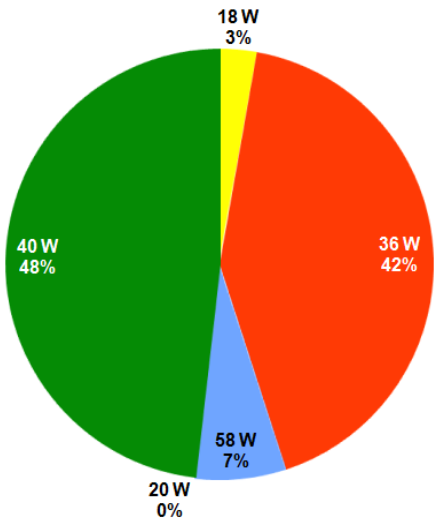


Figure 4. Structure of fluorescent lamps of different wattage in primary schools – number share (left) and power share (right)

Condition of luminaires corresponds with their age and maintenance quality. Situation differs from case to case. While in some schools with extra old luminaires these are kept functioning in a relatively good state, in other schools there are many luminaires with broken covers or bodies (fig. 5), broken or dirty diffusers, rusty reflectors, damaged or non functional sealing in luminaires of higher IP class (fig. 6) etc.

Figure 5. Damaged luminaire body with almost no optics – the luminaire do not fulfil its function

Figure 6. Dirt and dust inside of a luminaire with IP 54 ingress protection class

Luminaires with missing bottom cover in classrooms allow direct sights onto unshielded lamps with high luminance also in common observation angles, cause glare and underline the overall unhealthy lighting environment.

Blackboards are still illuminated by old type reflector projectors for incandescent lamps (fig. 7). Luminaires that have been installed in big amouts to schools about 30 years ago are today not functioning anymore or not used for several reasons. As teachers said, light is reflected from blackboard causing glare, blackboard is illuminated unevenly and visual conditions are simply better if these luminaires are turned off. What a contradiction! Therefore, many of these luminaires do not have any lamp inserted. Unfortunately, often new types of luminaires that are not suitable for the purpose replace the mentioned old types, e.g. luminaires with symmetrical reflectors as shown on fig. 8 sufficiently illustrate the result of such a solution. Reasons are in lack of adequate qualification of personnel.

Figure 7. Old type ferlector for illumination of blackboards

Inefficiency of optical parts is not the sole problem connected with luminaires. Electrical efficiency of fluorescent luminaires is low due to conventional magnetic ballasts with energy class D (old types) or C (relatively newer types), both banned in new type luminaires. Significant part of the consumption is taken by ballast. Disadvantages of conventional ballasts also include flickering of light what in combination of long time influence and young growing organism may cause psychological problems (neurosis). But flickering usually acts subconsciously and perceived unintentionally. Conventional ballast are characteristic also by unpleasant sound effect – a buzzing hum, quite considerable under certain conditions. As a paradox, most buzzing luminaires have been found during auditing in classrooms of musical orientation at a primary artistic school. Are children able to sensitively percept music at such a noisy background?

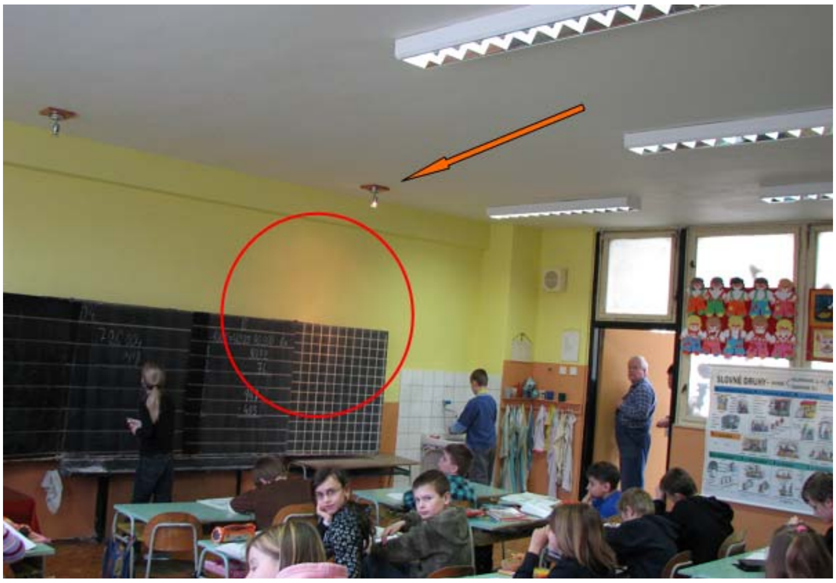


Figure 8. Blackboard illuminated with new but unsuitable luminaire types

2.3 Lighting systems

Besides problems mentioned above, geometry of lighting systems provide no preconditions for good lighting as well. Number of installed luminaires is not sufficient to cover the needed quantitative lighting parameters even if these luminaires are of most efficient and modern types. But some other classrooms are overlit (regarding the control of groups of luminaires) and there are real options to reduce the power consumption and keep the required lighting level. There are also serious problems with functionality of luminaires (fig. 12).

Figure 9. Illumination of a corridor with inefficient incandescent lamp luminaires

Figure 10. Illumination of a classroom in kindergarten with incandescent lamp pendant luminaires

Figure 11. Illumination of a PC room with incandescent lamp pendant luminaires

3. Energy saving potential

Energy savings can be achieved only by conscious and complex reconstructions of lighting systems and significantly depend on starting point described by audit for each individual building. Situation varies from very positive energy savings of about 30 % to increase of energy consumption after reconstruction when old systems are underdimensioned. But the same time it is necessary to mention that possibly energy savings have to be understood as a positive side effect and hygienic aspects should be the motor of lighting reconstruction, i.e. creation of high quality lighting environment in accordance with relevant regulations and standards. Overall rationalisation of lighting and increase of its efficiency and economy should be the result. Energy saving options are as follows:

- Replacement of luminaires by more efficient types, i.e. with more efficient optics, with less consuming and advantageous electronic control gears and with application of efficient light sources which will pass the standard requirements also from the point-of-view of light colour and colour rendering
- Luminaires should be replaced not piece for piece but with reconsidering the lighting system geometry, i.e. spatial distribution and position of luminaires such a way, that number of installed luminaires (defining investment costs) and installed power of lighting (defining operational costs) shall be optimized
- Addition and extention of lighting system where it is necessary to fulfil standard requirement or to upgrade the usage of building or its part
- Reconsidering the wiring of lighting circuits if replacement or reconstruction of electrical cables is planned

- Installation of movement detectors and/or daylight sensors if possible and applicable

- Restoration of regular maintenance system incl. cleaning of luminaires, replacement of lamps in prescribed periods of time, conduction and updates of maintenance plan etc.

Figure 12. Functionality of lighting is not rarely about 30 to 50 % of the total installed luminaires

Evaluation of any average figures of energy savings seems to be a difficult task due to big individual differences. From 41 audited educational buildings (see Table 1) energy can be saved by 3,6 % in average. Maintenance costs can be saved thanks to reduction of number of luminaires by 7,8 %. In all cases complete reconstruction have been considered, i.e. installation of new luminaires in a new arrangement. Positive energy savings are achieved even due to the fact that quality of lighting will significantly increase and lighting systems will be upgraded to a new level. Further works are aimed to evaluation of current (or starting) situation in terms of measured illuminance levels and conjunction of the data with energy savings in Table 1. For example, if installed power before reconstruction will be multiplied by difference between measured and required illuminance, relative (or nominal) energy savings will be much higher and illustrative. As shown by preliminary results of measurements, illuminance is only about (in average) one third of the requirement, then difference between old and new system will grow to tens of per cents. Though this can not be called “energy saving” anymore, it is a figural expression of the energy efficiency increase.

It is necessary to mention that lighting in some of the buildings in Table 1 is already reconstructed in the past year and many other reconstructions are under preparation.

B		n_{OLD} (pcs)	n_{NEW} (pcs)	P_{OLD} (kW)	P_{NEW} (kW)	S_N (%)	S_P (%)
AVE						7,8	3,6
1	AS	120	131	10,7	10,1	-9,2	5,6
2	AS	128	170	13,1	14,8	-32,8	-13,3
3	AS	184	134	15,7	11,5	27,2	26,7
4	AS	193	144	19	11,4	25,4	40,2
5	KG	278	251	16,6	18,2	9,7	-9,6
6	KG	131	129	7,9	10,7	1,5	-35,5
7	KG	89	69	5,9	6	22,5	-1,2
8	KG	55	77	3,9	6,9	-40	-77,7
9	KG	130	128	10,3	10,9	1,5	-5,5
10	KG	121	116	11,2	9,3	4,1	17
11	KG	245	169	22,3	15	31	32,8
12	KG	89	86	9,4	7,4	3,4	21,9
13	KG	203	140	16	11,5	31	27,8
14	KG	52	38	3,9	3	26,9	22,1
15	KG	272	292	23,8	28,5	-7,4	-19,4
16	KG	202	210	17,6	16,8	-4	4,7
17	KG	175	185	13,6	13,8	-5,7	-1,6
18	KG	36	43	3	4,1	-19,4	-37,8
19	KG	269	187	23,7	15,9	30,5	32,9
20	KG	125	121	10,3	10	3,2	3,5

B		n_{OLD} (pcs)	n_{NEW} (pcs)	P_{OLD} (kW)	P_{NEW} (kW)	S_N (%)	S_P (%)
21	KG	265	199	16,8	17,7	24,9	-5,4
22	LC	52	37	3,9	3,2	28,8	16,5
23	LC	32	41	2,4	3,3	-28,1	-36,3
24	PS	489	517	48,9	47,7	-5,7	2,5
25	PS	540	578	43,4	54,4	-7	-25,3
26	PS	1 159	736	99,1	70,6	36,5	28,8
27	PS	1 102	730	96	66,8	33,8	30,5
28	PS	1 296	961	130	90,5	25,8	30,3
29	PS	691	681	63,7	59,9	1,4	6,1
30	PS	341	413	23,9	35,9	-21,1	-50,4
31	PS	943	714	86,7	70,6	24,3	18,6
32	PS	732	618	78,9	60	15,6	23,9
33	PS	1 088	835	101	78,4	23,3	22,3
34	PS	931	632	86,4	62,1	32,1	28,1
35	PS	272	292	23,8	28,5	-7,4	-19,4
36	PS	480	425	38,9	40,2	11,5	-3,3
37	PS	380	294	30,1	28,7	22,6	4,5
38	PS	307	327	30,1	29,8	-6,5	1
39	PS	973	908	96,8	87,6	6,7	9,4
40	PS	376	433	42,4	42,8	-15,2	-0,9
41	PS	989	735	107	70,7	25,7	33,8

Legend:

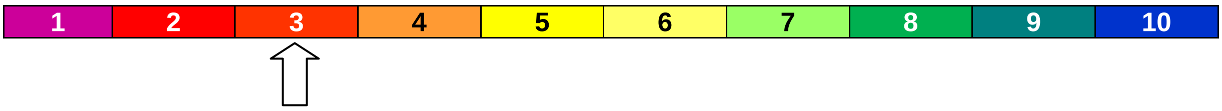
B - Building
$n_{OLD/NEW}$ - Number of installed luminaires for old and new lighting system
$P_{OLD/NEW}$ - Installed power of old and new lighting system
S_n - Reduction of the number of installed luminaires
S_P - Savings of the total installed power and energy consumption
PS = Primary School AS = Artistic School
KG = Kindergarten LC = Leisure Centre

Positive numbers mean savings, negative numbers stand for increase of number or power

4. Proposal of scale-type presentation of results

Auditing of lighting systems seems to be a powerful tool to initiate the reconstruction. During past two years many of audited buildings had undergo a renovation process based on seriously prepared lighting project. There also studies with comparison of estimated figures (reported in audits) and final figures taken from lighting projets. It is expected that audit should always slightly overestimate the results, not to be surprised by low outcome when ellaborating the project. Because then it is late to make corrections, financing of the reconstruction (including the project as a preparatory stage) is already agreed a signed by involved parties, namely if bank loans are to cover reconstructional expenses (the most of cases).

For decision makers it is very important to have a quick overview of essential information about the lighting. Practical usage of audit reports brought a need for development of a scale system, easy enough to be understood by everybody. For this reason a system of four scales have been proposed and today these are successfully used. Four scales give an indication of four different aspects of lighting. The scales are evenly divided to 10 levels which cover all practical situations. Suggested scales are shown below.



Technical condition and age of lighting system

1 – age > 50 years, 2 – age over 40 years and alarming condition, 3 – age over 40 years and bad condition or age over 30 years and alarming condition, 4 – age over 30 years and bad condition, 5 – age over 20 years and very bad condition, 6 – age over 20 years and well preserved condition, 7 – age over 10 years and bad condition, 8 – age over 10 years and well preserved condition, 9 – age over 10 years and very good condition or age up to 10 years and condition not adequate to the age, 10 – age up to 10 years and excelent condition

Efficiency of lighting system

1 – solely inefficient incandescent lamps, 2 – fluorescent lamps installed exceptionally, 3 – share of fluorescent lamps is less than 20 % and luminaires are inefficient, 4 – share of fluorescent lamps is less than 20 % and for inefficient luminaires 33 %, 5 – share of fluorescent lamps is less than 33 % and for inefficient luminaires 50 %, 6 – share of fluorescent lamps is less than 50 % and for inefficient luminaires 75 %, 7 – share of fluorescent lamps is less than 75 % or luminaires are inefficient and/or tubes are of old types, 8 – share of fluorescent lamps is more than 75 % but luminaires are inefficient and/or tubes are of old types, 9 – incandescent lamps are installed only in acceptable amount/applications and luminaires are of efficient types (depending on application area), 10 – the most recent and efficient approaches are used, featuring linear T5 lamps, electronic ballasts, efficient optics, compact fluorescent lamps etc.

Qualitative and quantitative lighting parameters

1 – illuminance level is neglectable, 2 – illuminance is less than 1/5 of required value, 3 – illuminance is less than 1/3 of required value, 4 – illuminance is less than 1/2 of required value, 5 – illuminance is less than 2/3 of required value and insufficient uniformity or glare, 6 – illuminance is less than 2/3 of required value, 7 – illuminance is less than required value and insufficient uniformity or glare, 8 – illuminance is less than required value or insufficient uniformity or glare, 9 – basic quantitative lighting parameters (illuminance,

uniformity, glare) are fulfilled, 10 – all quantitative and qualitative lighting parameters (incl. directioning of light, modelling, luminance distribution etc.) are satisfied or above common standard

Energy saving potential

1 – energy consumption after reconstruction will increase more than 30 %, 2 – energy consumption after reconstruction will increase up to 30 %, 3 – energy consumption after reconstruction will increase up to 20 %, 4 – energy consumption after reconstruction will increase up to 10 %, 5 – energy consumption after reconstruction will be approximately on the same level as before reconstruction, 6 – energy consumption after reconstruction will be slightly lower (savings up to 10 %), 7 – energy savings after reconstruction will be more than 10 %, 8 – energy savings after reconstruction will be more than 20 %, 9 – energy savings after reconstruction will be more than 30 %, 10 – energy savings after reconstruction will be more than 40 %

6. Lightplan for lighting system re-construction

For renovation of lighting system in educational building it is necessary to prepare a lighting project. Design can be done separately or together with the project of electrical installation, depending on investor's requirements and other factors. For lighting design, software tools are used for lighting calculations (e.g. Dialux) and drawing of installation (e.g. AutoCAD).

It is necessary to distinguish between old buildings and new installations. For old buildings, plans are already lost or missing and are not available anymore. For new buildings or installations, plans are under ellaboration (and building even does not exist) or recovery (if major changes are intended, going beyond the simple lighting renovation). Firs case is dominantly prevailing. It means, that there are no plans available. Now we concentrate on this case.

Before the lightplanning process starts, is it necessary to collect data from buildings. One factor is often playing against – time for ellaboration of lighting project is very limited otherwise financing options can be lost. Therefore, it is required to collect all necessary data as fast as possible. The list shows the most important items:

- **Taking pictures:** photodocumentation is one of the most important issues, because visit of the building can hardly be repeated and lighting design is just performed „at the desk". If there is sufficient picturing of every single room, i.e. ca 10 pictures per room by high-guality camera, „remote sight" to the room by designer is possible. Pictures are always renamed by an agreed form, having unique assigned room number included in filename (the room number corresponds to the plan).

- **Room dimensions:** Room dimensions are measured quickly by laser distance meters. In case of irregular shape, enough measurements should be performed.
- **Reflectance of room surfaces:** Recorded either during auditing or estimated from pictures, what seems to be of adequate accuracy taking into account other influences and accuracy of lighting design in general. If necessary, material properties and colority is also recorded.
- **Placement of workplaces** is evident from taken pictures and can be imported to lighting software.
- **Current arrangement of luminaires and lighting circuit topology:** In case of reconstruction it is important to prefer replacement of luminaires without changes in electrical installation or only to have minor modifications. Of course, arrangement of luminaires should follow the optimisation of lighting system if possible or effective.

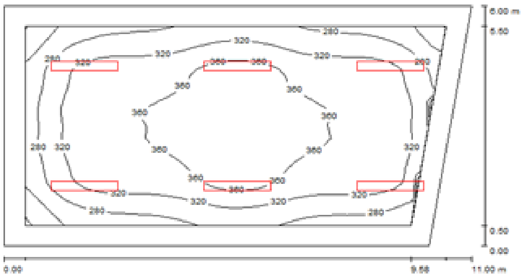
Such a way, for a single trained auditor it is expected to collect data from 200 rooms per day (assuming 10 hours of work). Usually primary schools have 100 to 200 rooms (in one or more buildings on a site), rarely less or more. Most of kindergartens have usually 50 to 100 rooms.

For ellaboration of a lighting design document there is a template prepared. Direct print from Dialux and similar approaches are space consuming and not applicable for buildings with big number of rooms. The template is made in a compact form. Figure 13 shows an example if input data table, where rooms are arranged to rows. Similar table is for output data (results). Each room then has a single A4 size page with picture (selection from shots), isolux diagram and all necessary input and output data. Example of a part of such page is shown on Figure 14. Dialux files are submitted together with the project and because this software is a freeware, it is available for the user and if necessary, it allows to check more detailed or specific results.

Nr	Room	B	P	M	DIMENSIONS				REFLECTANCE						WORKPLACE			MAINTENANCE FACTOR						
					l	w	h	A	R_C	R_F	R_{W1}	R_{W2}	R_{W3}	R_{W4}	h_{Ta}	h_M	w_b	I	MF	SZ	MZ	SS	ZS	ZP
					m	m	m	m^2	%	%	%	%	%	%	m	m	m	r	-	-	-	-	-	-
SUM								798,0																
1	Corridor	S	0		2,0	1,5	3,3	3,0	70	20	10	50	20	55	0,00	3,30	0,20	3,0	0,65	0,80	1,00	0,98	0,90	0,92
2	Washing room	S	0		1,0	1,5	3,3	1,5	70	20	50	45	40	50	0,85	3,30	0,20	3,0	0,67	0,80	1,00	0,98	0,90	0,95
3	Rest room	S	0		1,5	1,5	3,3	2,3	70	20	50	50	50	50	0,85	3,30	0,20	3,0	0,67	0,80	1,00	0,98	0,90	0,95
4	Closet	S	0		7,0	5,2	3,3	36,4	70	15	45	10	20	45	0,00	3,30	0,50	3,0	0,66	0,80	1,00	0,98	0,91	0,92
5	Common WC	S	0		5,6	3,0	3,3	16,8	70	15	45	50	50	50	0,60	3,30	0,50	3,0	0,65	0,80	1,00	0,98	0,90	0,92
6	Classroom	S	0		10,0	6,0	3,3	60,0	70	20	30	30	40	45	0,00	3,30	0,50	3,0	0,69	0,80	1,00	0,98	0,92	0,95
7	Entrance	S	0		5,0	3,0	3,3	15,0	70	15	15	45	50	35	0,00	3,30	0,50	3,0	0,65	0,80	1,00	0,98	0,90	0,92
8	Classroom	S	0		9,0	5,5	3,3	49,5	70	20	45	30	30	45	0,00	3,30	0,50	3,0	0,69	0,80	1,00	0,98	0,92	0,95

Figure 13. Part of an input data table for illustration

6	Trieda



Miestnosť

l	dĺžka miestnosti	10,0	m	h	výška miestnosti	3,30	m
w	šírka miestnosti	6,0	m	h_{Ta}	výška pracovnej roviny		m
w_b	šírka okrajovej zóny	0,50	m	h_M	závesná výška	3,30	m
A	plocha miestnosti	60,0	m^2				

R_C	odrazivosť stropu	70	%	R_W	odrazivosť stien	1	30	%	3	40	%
R_F	odrazivosť podlahy	20	%			2	30	%	4	45	%

DS	dostupnosť denného svetla	D	PO	pobyt osôb	T

Údržba

SZ	pokles svetelného toku zdrojov	0,80	MF	celkový udržiavací činiteľ	0,69	
MZ	mortalita svetelných zdrojov	1,00	I	Interval údržby	3,0	r
SS	starnutie svietidiel	0,98				
ZS	znečistenie svietidiel	0,92				
ZP	znečistenie plôch miestnosti	0,95				

Figure 14. Part of a project page for illustration

For presentation purposes, visualisation of typical and important rooms (classroom, office) are included in the project. Figure 15 shows an example.

Besides lighting calculation results and assumptions the project comprises also a plan drawing and on a separate sheets there are informations necessary for mounting staff (free of any unnecesary information for them). On this sheet there are luminaire coordinates, plan of luminaire placement as well as instructions for mounting and connection of luminaires.

To ease the work, standard room categories have been identified and coded. Codes are used for input and program automatically fills in the right room name which can be added by further text if necessary. Room categories are also used to identify requirements (illuminance level in lux, uniformity etc.) and for other purposes.

Finally, the whole project is evaluated from the point-of-view of possible energy savings. Installed power of the new system is compared to the old system as well as to estimations stated in the audit document. Project results should always be better than estimations.

Figure 15. Example of visualisation of a classroom

7. Conclusions

Status quo and conservation of the situation in lighting is given by legislative changes related to the governmental decentralisation when priorities have been focused particularly on basic functionality of schools. Today this is changing and schools concentrate on various development programmes. Financial funds and mechanism for renovation of buildings and their infrastructure as well as improvement of conditions for education are more and more available. Role of lighting is of high importance and should belong to highest priorities within renovation programmes. Auditing lighting systems should help the process significantly.

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