

Statistical Evaluation of Public Lighting Systems

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Public lighting (PL) offers a significant amount of energy savings even if keeping the required illuminance levels. All this is possible due to technical development since the time of installation of older systems. These are often more than twice to five times over their lifetime and do not provide illumination of sufficient quality, moreover with very inefficient lighting economy. On the other hand, some efforts of municipalities tend to draw inadequate actions in order to decrease the energy consumption for lighting.

Preliminary energy audits showed that situation has considerably changed in past decades – namely since 1996, when first broad inquiry investigation has been performed on a national level. But up to now there were no accurate figures available. At the end of 2006, a general inquiry supported by many institutions and managed by Slovak University of Technology and Energy Centre Bratislava took place. The same time, similar investigation ran on the European level, however, differently structured and oriented.

This paper is, amongst the others, focused on statistical results of the General Public Lighting Inquiry 2006 and the most important conclusions showing the state-of-the-art in terms of chosen parameters, including comparisons to previous figures from 1996 and in opposition to European averages. Besides the paper aims to concern with such items like statistical evaluation of public lighting projects designed by the Typhoon company in 4 towns (1000 – 2000 lighting points) in Slovakia.

Introduction

In order to succeed in application for supporting grants from European or international funds like UNDP and GEF, it is necessary to have relevant information on global figures and state-of-the-art in the field of public lighting. This is also needed as a preparatory study for implementation of the Directive 2005/32/EC [1] on Eco-design, also known as Energy Using Products (EuP).

Situation in the field of public lighting within the European Union differs from country to country and this involves the present state as well as options for energy savings. A comprehensive study on public lighting in EU countries [2] has been elaborated in 2006. This study is principally based upon inquiry investigation. However, there are doubts about the methodical approach. Overcomplicated inquiry led to less involvement of individual countries than expected. List of participated countries include Belgium,

Ireland, United Kingdom. Sweden, Denmark, Greece, Netherlands and Poland. However, even inquiries from these countries were not complete. Data from Slovakia have not been sent in time because regular General PL inquiry was planned to the end of 2006, mainly due to communal elections in 2006 (risk of low feedback).

From the PL study [2] follows that annual energy consumption for public lighting in EU25 countries counts as much as 35 TWh, what in per centual illustration makes 1,3 %. It is expected that in spite of further expansion of public lighting, annual energy consumption decreases to the level of 31 TWh in 2010.

Lamp structure of public lighting in EU countries consist of 49 % for high-pressure sodium lamps, 35,4 % for mercury lamps and 10,4 % for CFLs. 5,2 % portion belongs to metal hallide lamps.

It is necessary to point out that for countries which did not provide any feedback, the data are **very inaccurate** (cited source is CELMA). For Slovakia, for instance, the number of inhabitants per luminaire is 25, much more than in reality (country average is 12). The study [2] though operates with reciprocal indicator – number luminaires per capita, what is really not practical, values are far beyond the decimal point.

Scientific goals

After years of relative inactiveness in public lighting, first general inquiry in Slovak Republic has been realized in 1996 [3] - [4] in co-operation between the Faculty of Electrical Engineering and Information Technology STU, Slovak Electric Company and Ministry of Environment. This inquiry brought a very interesting survey and started up a whole series of activities aimed to implementation of rational approach to public lighting re-constructions in order to benefit from energy savings. These activities involved pilot projects, seminars for representatives of municipalities, general information campaign and propaganda. Since that time more than 50 energy audits have been elaborated, modernisation or re-construction of public lighting in many towns and villages have been designed and realized. Data from the First PL inquiry became very useful for quick estimation of necessary figures to rapidly survey unknown systems. For example, from number of inhabitants one can estimate the number of luminaires, number of distribution boxes, costs for reconstruction etc. Data of the First PL inquiry have been also adopted by the Statistical Institute of the Slovak Republic.

Now, at the end of 2006, exactly 10 years after the First inquiry, necessity to upgrade the results of inquiry and need for more up-to-date figures raised. Today, the activities in public lighting are supported mainly from environmental funds of the UNDP [5] and GEF coordinated by Energy Centre Bratislava as well as by R&D projects (see acknowledgement).

Besides it is also very useful to find out the statistical structure of lighting classes according to the european standard [6] as resulted from several PL projects in slovak towns (the condition is that project should cover the whole municipal territory and cannot be limited to only certain quarters or main streets etc.).

This might be useful for estimation of energy demand of renovated public lighting systems. Up to now, this was only estimated upon input power conversion table between mercury lamps (to be replaced) and new sodium lamp installations. However, such an approach is very inaccurate. Estimation based on lighting class structure is expected to be more closely to the result of renovation.

Goals of statistical investigation can be listed as follows:

- preparation and realization of the Second PL inquiry focused on recent state of public lighting systems throughout Slovakia
- statistical evaluation of lighting classes drawn from real complex public lighting re-construction projects

The Second PL inquiry has been prepared and elaborated again in co-operation of several institutes, with participation of private companies and under surveillance and supervision of the Energy Centre Bratislava (NGO) who also managed the dissemination of questionnaires and processing of the feedback.

Methodology

Structure of the questionnaire has been prepared in accordance with broad experience gained during elaboration of audits, passports and projects of public lighting systems in Slovak towns and villages. The questionnaire is compiled such a way that it must be as compact as possible (not to overwhelm respondents) but the same time it should contain all the necessary information. Otherwise the feedback may be very low. So the questionnaire is composed to only 1 sheet A4, back side of this sheet is reserved for information how to fill the questionnaire. Questionnaire is prepared in a widely used spreadsheet format MS Excel, available for almost all respondents. Dissemination ran completely through electronic (e-mail) channels to all towns and villages in Slovakia, therefore with 100 % coverage.

Processing of feedback is automated. Each sheet is registered via an ID number, furtherly it is inserted as an Excel worksheet in a common file. Through the ID number the summarizing table draws all the necessary data. Averages and other indicators are calculated also automatically.

Results and Discussion

Total 254 municipalities (8,76 %) participated in the investigation. This number is very high to confirm the validity of investigation, it is far beyond any expectations and significantly exceeds the feedback from the First PL inquiry. From a different point-of-view we can take into account number of inhabitants. The inquiry covers total 1,41 mio people, what stands for more than a fourth of the country (25,7 %).

Structure of towns and villages according to number of inhabitants illustrates the TAB 1 (it is quite necessary to relate the number of inhabitants to the total 5 mio for Slovakia or 400 000 for Bratislava as the capital). Prevailing part of respondents falls to the category between 3 000 and 6 000, i.e. with 300 to 600 luminaires.

Installed power of the sample involved makes 13,46 MW, declared functionality of PL systems is about 95 %. However, this figure is very doubtful. This could be only taken as a rate of functional lamps, however, in very bad-condition or damaged luminaires with almost no optics and covers to protect the lamps.

Average figures, what in fact are the most important results of statistical evaluation, are presented in TAB 2. For comparative and tendentious reasons there are also data from 1996 given in the table.

Inhabitants	Feedback	Rate (%)
1 - 500	58	23,0
5 00 – 1 000	64	25,4
1 000 – 3 000	82	32,5
3 000 – 6 000	21	8,3
6 000 – 1 0000	6	2,4
1 0000 – 1 5000	4	1,6
1 5000 – 3 0000	8	3,2
3 0000 – 4 0000	2	0,8
4 0000 – 5 0000	2	0,8
5 0000 – 8 0000	3	1,2
8 0000 – 1 00000	1	0,4
1 0000 a viac	1	0,4

TAB.1 Statistical structure of respondents according to the number of inhabitants

	1996	2006
Lamp structure Mercury/Sodium/Other:	43 / 54 / 3 %	11 / 73 / 16
Annual number of hours burned:	3 580 h	3 343 h
Capita per luminaire:	12	9
Installed power per capita:	12,5 W	9,5 W
Installed power per 1 km of street:	4 kW	2,8 kW
Average spacing of poles:	48 m	40 m
Average installed power per 1 distribution box:	7,9 kW	4,6 kW
Average luminaire power:	173 W	100 W

TAB.2 Summary average values of public lighting systems in Slovakia

Table 2 shows that there is a very significant shift in the lamp structure. Portion of mercury lamps much decreased while now there is majority of sodium lamps and CFLs have a raising trend in public lighting (13 %). Unfortunately, CFLs are used not in suitable applications as a simple luminaire replacement, often in an inadequate geometry (e.g. to 12 heights) and for roads with higher demands to lighting (e.g. ME4b or higher).

Several indicators further give an evidence that installed power of public lighting decreased as a result of energy saving actions, both rational and inadequate. However it is necessary to say that average **100 W per luminaire** is usually reached for completely reconstructed public lighting systems with average structure of lighting classes.

TAB. 4 gives very important data on current average lamp structure of public lighting. It is clear that the major portion is represented by 70 W sodium lamps. Mutual rate of 70/100/150 W lamps is in very good accordance with average structure of renovated systems. Structure of poles is presented in TAB.5.

Lamp type	Total	50 W	70/80 W	100/125 W	150 W	250 W	400 W	36 W	2x36 W	Other
Mercury	11,4	2,5	12,7	49		33,1	2,8			
Sodium	72,7	2,8	51,9	31,7	4,7	8,4	0,45			
CFL	12,7							80	17,5	2,5
Other	3									

TAB.4 Actual lamp structure of public lighting in Slovakia (in %)

Pole type	Rate (%)
Concrete mast with overhead lines or cables	81,3
Concrete low-height poles with burried cables	1,5
Steel or galvanized poles with overhangs (arms)	8,5
Steel or galvanized poles without arms	6,9
Other	2,2

TAB.5 Structure of poles for public lighting

Overall condition and future plans	Podiel (%)
PL system is new or renovated	31,1
Reconstruction under consideration	26,8
Only replacement of luminaires is planned	38,2
Only usual service and reparation in the near future	49,2
No reconstruction or renovation in plan	5,5

TAB.6 Future plans with public lighting systems

Generalized information about future plans with public lighting systems is given in TAB 6. It is quite surprising that more than 30 % of systems is new or renovated. If so, quality of these works is quite doubtful. Results show that there is still lack of a rational and systematic approach to the public lighting. Shortcomings can be seen in lack of relevant information (in spite of annually organized seminars on public lighting and other very fruitful activities) e.g. on technical options, benefits, financing – what necessarily calls for further increase and continuation of education and propaganda.

Most of municipalities plan to solve the problems relating public lighting by means of their own financial sources, which are always limited, indeed. As like municipalities are afraid to rely on e.g. third party financing or co-financing (EPC, for instance), though many successfully realized projects showed that this way may lead to very positive relationships with all parties satisfied. Details on financing priorities see in TAB.7.

Financing priorities of municipalities	Up to now	Plan
Bank loan	2,4	4,3
Energy Performance Contracting (EPC)	2,0	10,2
Own funds	37,0	29,9
Other	0,8	7,1

TAB.7 Options for financing public lighting reconstructions (rates in %)

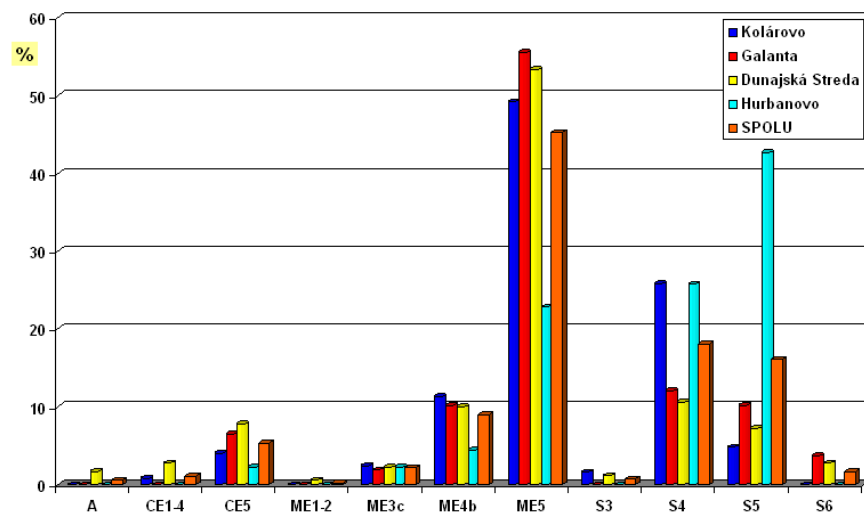
Finally, TAB 8 and FIG 3 to 4 illustrate the structure of lighting classes for roads and sidewalks as a result of complex reconstruction projects in 4 slovak towns. ME5 is the lighting class prevailing for motorized traffic roads, S6 for sidewalks. These figures are just for general information, more detailed analyzes have been performed, published and are available in the case of interest.

	Lighting class										
	A	CE 1-4	CE5	ME 1-2	ME3c	ME4b	ME5	S3	S4	S5	S6
Kolárovo	0,0	0,8	4,0	0,0	2,4	11,3	49,2	1,6	25,8	4,8	0,0
Galanta	0,0	0,0	6,5	0,0	1,9	10,2	55,6	0,0	12,0	10,2	3,7
Dunajská Streda	1,7	2,8	7,8	0,6	2,2	10,0	53,3	1,1	10,6	7,2	2,8
Hurbanovo	0,0	0,0	2,2	0,0	2,2	4,4	22,8	0,0	25,7	42,6	0,0
SPOLU	0,5	1,1	5,3	0,2	2,2	8,9	45,3	0,7	18,1	16,1	1,6

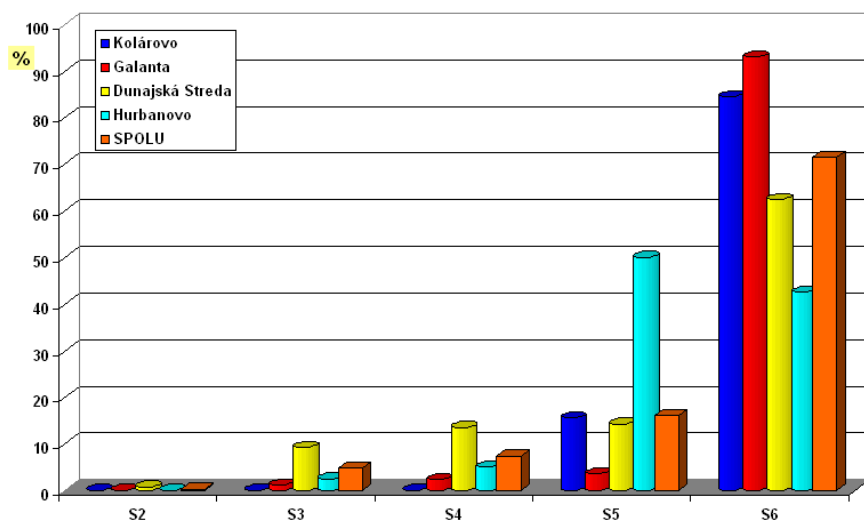
TAB.8/1 Structure of lighting classes for roads with motorized traffic with sidewalks (rate in %)

	Lighting class				
	S2	S3	S4	S5	S6
Kolárovo	0,0	0,0	0,0	15,6	84,4
Galanta	0,0	1,2	2,4	3,5	92,9
Dunajská Streda	0,7	9,2	13,5	14,2	62,4
Hurbanovo	0,0	2,5	5,0	50,0	42,5
SPOLU	0,3	4,8	7,4	16,1	71,4

TAB.8/2 Structure of lighting classes for pedestrian areas (rate in %)



OBR.3 Structure of lighting classes for roads with motorized traffic with sidewalks



OBR.4 Structure of lighting classes for pedestrian areas

Summary and Conclusions

The Second general public lighting inquiry showed that during past 10 years there was a significant modification of the lamp structure. We have more compact fluorescent lamps, however, not installed in accordance with relevant rules and standards. On the other hand, we benefit from high-pressure sodium lamps and mercury lamps are continuously decaying in public lighting. 254 respondents covering 13% of all municipalities and over 25 % of inhabitants give the performed inquiry a stamp of validity.

Gained statistical indicators can be generalized for the whole country conditions, to derive overall data. These are presented in TAB 9, once again in comparison to previous data obtained in 1996.

	1996	2006
Number of luminaires	458 000	472 000
Installed power of public lighting	79 MW	52,3 MW
Annual energy consumption of public lighting	250,9 GWh	223,1 GWh
Annual energy consumption of public lighting at 100 % functionality	358,5 GWh (estimation)	235 GWh (at 5 % failure)
Assumed annual energy consumption after complete re-construction of public lighting	145,9 - 213,3 GWh	not processed
Annual operation costs (energy + servicing)	not processed	56 mio USD

TAB.9 Generalized data on public lighting for the country as a whole

It is of high importance to mention that new results cannot be simply applied to old systems, which are conserved more than 10 years. For preparation of re-construction projects it is necessary still to use indicators from the First inquiry, though, to assess the rate of possible changes during past 10 years.

References

- [1] Directive EC 2005/32/EC on energy using products.
- [2] VanTichelen, P. et al: *Preparatory Studies for Eco-design Requirements of EuPs – Final Report*. Lot 9: Public Lighting. 2007, 344 s.
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- [4] Gašparovský, D.- Smola, A.: *Public Lighting in Slovakia - A Comparison Study*. In Proc: Lighting Architecture Design, Varna 2001, pp. 39 – 44
- [5] Webpages of the UNDP: www.undp.org
- [6] TR 13201-1: 2005

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