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The objectives of the journal consist of the presentation of the results of the lighting research activity, the dissemination of the lighting knowledge, the education of the interested people working in public administration, constructions, designers, dealers, engineers, students and others.

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LIGHTING AND ENERGY

Dr. Florin POP,
Professor

This issue is based on the papers presented at the international conferences on lighting ILUMINAT 2007 Cluj-Napoca. It is edited under the frame of the EnERLIn IEE program.

The work of **D CARTER** addresses the design criteria necessary to achieve satisfactory user conditions under the light received from the tubular daylight guidance systems (TDGS). The research survey was developed on 13 locations – offices – with 168 occupants. Statistical techniques results of the users views show that TDGS were inferior to windows in delivery of both quantity and quality of daylight; a view of even distant windows has a more beneficial effect on perceptions of lighting quality than that of overhead guide output devices; a view out is important. The results suggest that TDGS are considered inferior to windows in delivery of most aspects of quantity and quality of 'daylight' The capital cost of a suitable TDGS is likely to be several times that of electric system and raises the question of whether the benefits of the daylight delivered by the system are sufficient to offset this. Guidelines for design of future systems are suggested.

Liisa HALONEN and **E TETRI** are promoters of The IEA Annex 45 – Energy Efficient Electric Lighting for Buildings, an international co-operation project on energy-efficient lighting. The objectives of project are: to identify and accelerate the use of energy-efficient high-quality lighting technologies and their integration with other building systems; to assess and document the technical performance of existing and future lighting technologies; to assess and document the barriers preventing the adoption of energy-efficient technologies; to propose means to resolve these barriers. A case office lighting was developed on the HUT Lighting Laboratory, a demonstration building for lighting research. Three sets of rooms each with different lighting control system was chosen for the measurement and assessment. Due to the combination of dimming according to daylight and occupancy control, the room with the highest specific power of 2.54 W/ (m^2·100 lx) used the lowest annual energy consumption of 20 kWh/m^2.

V MAIER and **S PAVEL** are concerned to the luminance variation assessment in road nocturnal lighting, by applying the estimation methods of the flicker indicators to the road lighting systems, making experimental determinations and computer added analysis. The periodical variations of the visual sensations can be induced by the following causes: luminous flux fluctuations, fluctuation in time of the light spectral composition, the human subject movement in a visual field, the movement of some successive lighting sources versus the human observer. The luminance fluctuations amplitude is associated with the flicker generating cause which could be as well the movement of the drivers in an un-uniform field of luminances and the relative movement of other vehicles in comparison with observer/ driver. The luminance fluctuations were measured in a lighting system considered as characteristic for the urban roads. The admitted amplitudes of the fluctuations, determined in accordance with the CEI norms are situated between 2.8% at 0.2 Hz and 0.73% at 1.5 Hz; consequently, the admissible amplitudes of the fluctuations are 8÷40 times greater in both cases.

F POP and **D BEU** present some results of two programs for promoting lighting energy efficiency and energy saving measures in residential buildings. Two questionnaires surveys were developed in 2005/2006. In the first survey – November 2005 - targeted to the usage degree of GSL and CFLs in households in Western Romania - 295 replies - the average use of CFLs was 1.91 units. The second survey – November 2006 - 169 answers from the custom people of two electric equipment dealers pointed out CFLs: 4.06 unit per people. It seems to be too great, mainly due to the fact that the questioned people known well the energy efficient lamps. The further Promotional campaign will pointed compact areas – all households from a street with single family houses, a residential district of bloc of flats in a city, a county village.

R SAN MARTIN PARAMO presents an historical evolution of the artificial lighting. It is underlined the great contribution of the XX century to the knowledge and the quantitative and qualitative improvement of the light sources and visual processes to improve the human life, in its quality, security and satisfaction aspects. Environmental repercussions of Artificial Lighting point in three factors - Energy consumption, Generation of residues and Light pollution. In the last, there are emphased the matters of Artificial lighting and human health and Globalisation effects on artificial lighting and equality.

G Zissis and **M AUBES** estimate key results of the first two years operation of the EnERLIn project. The consortium work is focussed on the better promotion of Compact Fluorescent Lamps (CFL) for residential use. The project web page is fully operational and accessible and a number of documents are yet available in both intranet and public download pages. Data from several countries concerning CFL market and residential use have been collected, analysed and consolidated. The potential for the implementation of environmental friendly and cost saving lighting measurements is still very high. The main outputs from the project will be the creation of new European CFL-Quality Charter, the design of attractive CFL promotional campaigns, the creation of CFL quality criteria and comprehensive databases.

The main objectives of the **H St GRIF** thesis are the identification and study of the photo parameters determining the quality of the lighting produced by a certain lighting installation, the control/regulation strategies, the control devices and the sensors used in lighting installations, the implementation of a lighting control system with the possibility of implementing the algorithms designed using artificial intelligence techniques.

Mihaela POP approaches in her thesis one of the components of indoor environment – the lighting quality. One The main contribution is regarding to the development of an integrated system of quality evaluation in indoor lighting installations - proposal of a System to appraise the quality of indoor lighting installation, evaluation of its weighing factors, analysis of responses to the questionnaires regarding the quality of indoor lighting installation using the method of hierarchical classification, quantification of "lighting system energy efficiency" parameter, quality appraisal toolkit, and experimental research.

C ŞUVĂGĂU continues his very interesting and exhaustive column, "The Lighting in The New World", with a presentation of an Adaptive Lighting - Case Study. During 2005, a team of researchers from the National Research Council of Canada (NRC) conducted a field study on four floors of an office building in Vancouver, British Columbia, Canada, occupied by the province's electrical utility, BC Hydro. Thanks to recent technological advances, designers can now give workers control of luminaires and light levels to meet their individual needs. New intelligent control systems provide thus workers with the benefits of a much more personalized lighting experience, and save energy without compromising visual comfort.

TOWARDS DESIGN CRITERIA FOR DAYLIGHT GUIDANCE SYSTEMS

David CARTER
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Tubular daylight guidance systems (TDGS) are linear devices that channel daylight into the core of a building. CIE 173:2006 offers guidance on some design issues but does not specify the design criteria necessary to achieve satisfactory user conditions. This work addresses this problem using field studies of working buildings lit by daylight guidance. Data on achieved lighting conditions, and user views on quantity and quality of the lit interior, were gathered and statistical techniques used to link the two data sets. Results show daylight contributions of the order of 25% of total design workstation illuminance with daylight factors ranging from 0.2% to 1.6%. User views suggest that TDGS were inferior to windows in delivery of both quantity and quality of daylight. Guidelines for design of future systems are suggested.

Keywords: offices, lighting, daylight, guidance systems, light pipes, costs, benefits

1. Introduction

Tubular daylight guidance systems (TDGS) are linear structures that channel daylight by means of optical interactions into the core of a building. The development, over the last decade, of materials with high specular reflectance has led to a large number of passive zenithal systems, the most commercially successful type, being installed in many parts of the world. Passive zenithal tubular daylight guidance systems consist of a clear polycarbonate dome that accepts sunlight and skylight from part or the whole sky hemisphere; a rigid or flexible tube lined with highly reflective material to redirect the light; and light output devices, commonly diffusers made of opal or prismatic material or an array of Fresnel lenses.

There has been a considerable research effort on TDGS over the last decade. Initially this concentrated on light transport materials and devices but latterly a number of methods of predicting light delivery and/or distribution within a building interior have been developed which form the basis of CIE173:2006 (1). One major area that has not been researched is design criteria to give satisfactory user conditions. Existing design norms for electric or daylight design have only limited applicability in this respect since TDGS share few physical characteristics with conventional lighting. More fundamentally, although TDGS are sold on the notion of delivering ‘daylight’, there is little understanding of the circumstances under which light emerging from a guide can be regarded as daylight.

This paper reports surveys of achieved conditions in a number of TDGS and an investigation of human response to the systems. These were related to characteristics of the building and its lighting system and permitted investigation of quantity and quality of daylight delivered by the systems and other issues. The rooms were generally large and contained areas where TDGS were the main daylight source. They also offered the opportunity to study the influence of different types of output device, different layouts of output device, and the presence or absence of TDGS in similar areas. This study uses average DPF and DPF at each individual workstation as a measure of daylight penetration. The thirteen offices studied were located in the UK. Two of the TDGS were in new buildings, two were included as part of a complete redesign of building lighting and the rest were retrofitted to existing accommodation. The offices were mainly open plan (average area of 257m^2, room index from 1.76 to 5.8, average number of users 17). Seven of the installations were windowless; in four the windows were so remote as to provide no workstation illuminance in the area studied; and the others had small vertical windows. Only 15% of the workstations studied were in rooms equipped with windows. All rooms were equipped with electric lighting (mainly mirrored louvered down-lighters). The guide output devices were circular domed or flat opal diffusers, or 600x600 square lensed panels, all located in suspended ceilings. In the majority of rooms the output devices were in regular arrays over the whole area studied, but in others they lit only part. As the surveys took place in working areas, the data-collection methods were necessarily limited to those that did not interfere with the running of the organisation. Detailed information on room layout, lighting layout and control, window and blind details was collected and an illuminance measurement made at each workstation firstly for a combination of electric lighting and daylight and secondly, if possible, for daylight only. A questionnaire filled in by 168 occupants related to occupants' personal and employment circumstances, daylight in buildings, photometric conditions at workplace, and perceptions of the lit environment. The questionnaire format was either rating scales (1=low effect to 5=high effect) or binary tick box.

2. Results

2.1 Achieved lighting levels

Table 1 summarises the arithmetic average of the measured workstation illuminance values from combined electric lighting and daylight, and that due to daylight alone. It was only possible to measure daylight in three rooms, the daylight contribution in the remaining rooms being estimated using the average daylight penetration factor (DPF) and/or average daylight factor (DF) together with a measured external illuminance. DPF is analogous to DF and is the illuminance received at a point indoors via a light guide expressed as a percentage of the global exterior illuminance. Additionally DPF for each individual workstation from all guides was calculated using the point by point method of CIE 173 and these are shown in Figure 1 (1). It is clear that half of the values are below 0.5% DPF, and only 10% above 1.0% DPF. There were positive correlations between guide aperture area and individual DPF guide aperture area, and between individual DPF and workstation daylight illuminance.

Table 1 Summary of lighting levels in installations

Building	Average illuminance across all workstations (lux)		Daylight apertures as % of total wall or ceiling area		Average work plane DPF+ DF (%)	Output device nadir luminance (cd/m^2)
	Electric and daylight	Daylight only: Measured or *estimated*	Windows	Guides		
1.1	930	211	3	1.9	1.1	5000
1.2	846	410	4	1.4	1.1	8200
4.2	564	*280*	0	0.7	0.4	8200
13	700	*430*	0	2.3	0.8	13000
21.1	932	*128*	10	0.4	1.6	780
21.2	507	*38*	0	0.4	0.26	3900
21.3	567	*160*	0	0.4	0.26	2700
22	332	72	0.5	1.0	0.6	2700
23.1	647	*206*	0	3.2	0.59	4900
23.2	524	0	0	0	0	
23.3	949	*210*	0	4.3	0.6	4900
24.1	279	*70*	6	0.9	0.68	3300
24.2	236	*15*	6 (atrium)	0	0.1	
25.1	372	*150*	0	2.3	0.22	6500
25.2	455	*140*	0	2.2	0.21	6500

About a quarter of the occupants were working below the Society of Light and Lighting (SLL) recommended values for offices (300 - 500 lux) with some 40% above this range (4). Although the daylight systems arguably contribute some over-lighting, only 10% of the workstation daylight levels would on their own satisfy SLL minimum requirements for offices. The daylight contribution generally represents about 25% of total illuminance. The daylight contribution is influenced by a number of factors, notably the lower number of, and light output from, the guides relative to that of the electric luminaires; the distance from workstations to the output devices; and the small size of windows, and distances from windows to workstations. Inspection of Table 1 shows that the number of output devices is between 25 and 50% of the number of luminaires. A typical 600 mm square luminaire has an output of about 5000 lumens. By comparison individual guide output in the installation with the highest recorded external illuminance values was

8700 lumens (Building 4.2) and that for the lowest (Building 22) was 1500 lumens, both estimated using the CIE173 method. In rooms lit by regular arrays of TDGS most workstations were within 2m (on plan) of an output device, but this was exceeded in some cases in buildings 4, 21, 23 and 25. In general window areas in all rooms were either very small or were so far from workstations as to make a negligible illuminance contribution.

2.2 User views of lighting quantity

In terms of lighting quantity around 50% of occupants were satisfied with the amount of light on their workstations with more complaints of too little light than too much. Only about a third were satisfied with the amount of daylight, over 7 times as many preferring more rather than less. No relationships were observed between any of the responses relating to the amount of light and actual levels of total or daylight only illuminance recorded. There is a weak relationship between perception of amount of daylight and both individual workstation DPF and with average DPF calculated using the CIE method, but no relationships between perceptions of total amount of light on workstations and individual DPF. This suggests that DPF in any form is not a reliable indicator of user perception of quantity of light. Users were also asked to assess whether the majority of light on their workstations was daylight. In buildings with windows 40% of users regarded daylight as the main source. In windowless spaces only 7% considered daylight (presumably via the guides) the main illuminator. If the individual DPF values were divided into three groups 0 to 0.499%; 0.5 to 0.999%; and 1.0 to 2.0% (the upper limits of these groups representing the approximate logarithmic scale of equal visual stimulus) the proportion of users regarding daylight as the principal illuminant were 9%, 10% and 33% for the respective groups.

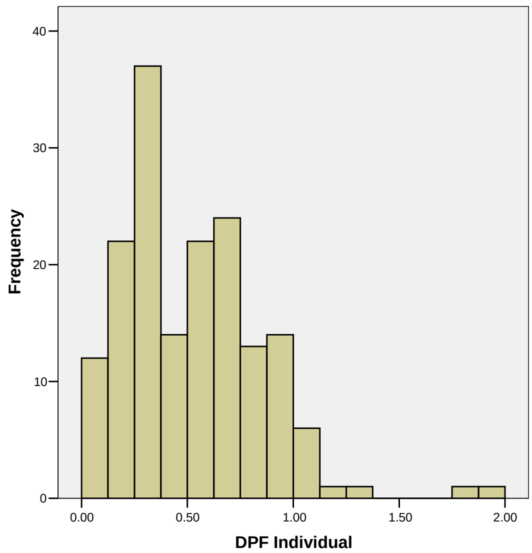

Figure 1 Distribution of individual DPF values

There were statistically significant differences for perceptions of amount of individual workstation daylight between buildings with and without windows, but not for amount of total amount of light. Given that the buildings were deep plan, predominantly electrically lit, with minimal windows this is not surprising.

2.3. User views on lighting quality

The quality of the human visual experience within working buildings is influenced by a number of factors including perception of surface luminance, glare and communication with the external environment. Only 32%

liked their visual environment across the whole dataset, 60% in the rooms with windows and 27% in windowless rooms. This suggests that a view of even distant windows has a more beneficial effect on perceptions of lighting quality than that of overhead guide output devices. About one quarter of users can detect weather and diurnal variation in windowless rooms, presumably by changes in brightness of the guide output devices but the response to the question on external view in windowless spaces suggests that TDGS are not as effective as windows in providing this. Taken together the above suggests that view out is important. Users rated the brightness of the scene in front of them and also that of the ceiling. Figure 2 shows the response to the latter across all visits, that for the scene in front being similar. The majority of users are satisfied with the brightness of the scene in front of them and also that of the ceiling, but the numbers reporting the scene too dim was greater than those reporting too bright. Mean assessments for rooms with windows are close to the neutral point of three, but are much lower in the large windowless rooms. The windows are both of small size and remote from the majority of workstations and thus despite their inability to contribute markedly to surface brightness their absence appears to adversely influence perception of brightness.

The degree of Satisfaction with brightness over all data sets is higher in all cases than the corresponding values for quantity of light. There was no statistically significant difference in glare rating between installations with and without windows. This is consistent with the complaints of too little light on workstations and with the low luminance luminaires and output devices used.

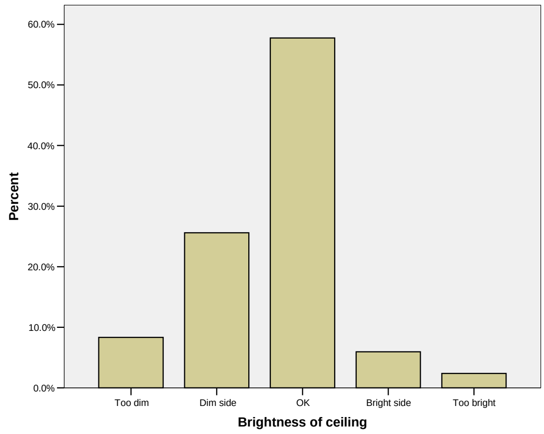

Figure 2 User assessment of brightness of ceiling

Table 2 shows average responses to the questions on light distribution, light colour, appearance and environmental impact for the whole data set and separately for buildings with and without windows. Although generally rooms with windows performed slightly better, a Mann-Whitney U test showed no statistically significant differences in response with and without windows. This is to be expected given the window configurations and room size. Opinion on shadows tended toward the soft side suggesting that the TDGS moderates the harsh downward modelling of the electric lighting. Given that electric lighting predominated it is perhaps not surprising that the mean answer on distribution of light was close to the neutral point for all cases. Questions on appearance of the light and appearance of user complexion attempted to investigate the colour properties of the installations. Mean response to the two questions was similar with more favourable opinion in rooms with windows. The answers on environmental friendliness of the systems hint that this concept is linked to the provision of windows. The neutral response to whether the systems fit into the room may suggest that the output devices are perceived as similar to luminaires.

Table 2 Mean response and standard deviation of answers relating to on light distribution, light colour, appearance and environmental impact (1 = unfavourable and 5 = favourable)

	Shadows	Distribution	Appear.	Complex.	Environ.	Fits in
Whole set	2.25 *(1.0)*	2.94 *(1.1)*	2.80 *(0.98)*	3.0 *(0.96)*	2.55 *(1.0)*	2.94 (*1.0)*
With windows	2.50 *(1.2)*	3.08 *(1.2)*	3.10 *(1.0)*	3.3 *(0.86)*	3.10 *(1.2)*	3.1 *(1.0)*
Without windows	2.20 *(0.97)*	2.90 *(1.1)*	2.70 *(0.93)*	2.5 *(1.0)*	2.40 *(101)*	2.9 *(1.03)*

The rooms offered the opportunity to study user opinion at workstations located under different layouts of output devices. Luminaires were in all cases located in regular grids across the room area. Some output device grids were of this nature (107 workstations) but in some rooms only part of the area was lit using TDGS (61 workstations). In both conditions only some 30% of users liked the visual environment. A Mann-Whitney U test showed no statistically significant differences in response to questions on perceived amount of daylight, distribution of light or appearance of the room. However there was a statistically significant difference between perception of total amount of light on workstations but this however may be due to a significant difference between the total workstation illuminance in the two cases.

Table 3 Mean response for 'elements of daylight' for each Group DPF. (**Whole data set**, with windows, without windows*)*

Element of daylight	0 - 0.49% DPF	0.5 - 0.99% DPF	over 1.0% DPF
Amount of daylight (mean)	**1.8,** 2.5, 1.6	**1.9**, 2.2, 1.9	**2.6**, 2.3, 2.7
Time (% answering Yes)	**40**, 81, 31	**24**, 20, 25	**30**, 25, 33
Weather (% answering Yes)	**30**, 81, 18	**39**, 60, 27	**40**, 66, 17
External view (% answering Yes)	**19**, 63, 9	**11**, 40, 9	**20**, 50, 0
Distribution of light (Mean)	**2.8**, 2.8, 2.8	**2.9**, 3.2, 2.9	**3.7**, 2.5, 3.6
Appearance of room (Mean)	**2.6**, 2.9, 2.6	**2.8**, 2.8, 2.8	**3.7**, 3.7, 3.7
Facial appearance (Mean)	**2.8**, 3.1, 2.7	**3.1**, 3.0, 3.1	**3.4**, 3.6, 3.0

Circular flush or dished devices lit 97 workstations, the remainder lit using square devices giving similar total or daylight-only illuminance conditions in the areas lit by both types. Generally square output devices were rated more favourably than circular versions, but particularly total workstation illuminance was perceived to be higher for similar physical conditions. This may be because the square device resembles a luminaire.

2.4 The components of 'daylight'

The popularity of daylight is due its ability to deliver light of high illuminance with spatial and temporal variation, good spectral composition, and also contact with the exterior and a view. Table 3 shows responses for grouped workstation DPF for the whole data set, and split with and without windows. The perception of the main 'components of daylight' was studied with increase in DFP and, unsurprisingly, perception of amount of daylight increases, as does assessment of colour, evenness of the lighting and detection of weather changes. There is no increase in perception of external view or diurnal variation which suggests that even the largest TDGS aperture areas are inferior to windows in these respects.

2.5 Comparison of areas with and without TDGS

Buildings 21, 23 and 24 offered the opportunity to compare similar areas lit solely by electric lighting with those additionally containing TDGS. There were 49 users in areas with TDGS (mean workstation illuminance = 511 for total illuminance, and 130 for daylight-only), and 31 workstations in areas without TDGS (mean workstation illuminance = 371 for total illuminance, and 23 for daylight-only). There were significant differences in both total and daylight-only workstation illuminance between the areas suggesting that the daylight contribution from the TDGS had a marked effect. However a Mann-Whitney U Test only showed a statistically significant difference in perception of evenness of light distribution with rooms with guides appearing more evenly lit.

3. Discussion

The contribution of daylight (average DPF across all rooms 0.65%) was in most cases about 25% of total workstation lighting but was up to 50% of electric lighting illuminance. The disparity in 'installed load' meant the electric lighting was the dominant. Many of the rooms were surveyed on days when external illuminance values were low so that there is potential for substitution of daylight for electric light. The absence of daylight linking allowed diurnal variation to increase illuminance above electric lighting design values but prevented energy savings even when daylight was capable of satisfying SLL requirements. This unsatisfactory result may be due to either the scheme designers deliberately trying to create predominantly electrically-lit spaces with TDGS as a palliative, or a failure to create a day-lit space because the technology was not fully understood or appropriate design guidance available.

Daylight penetration was quantified using the methods described in CIE 173 and the main metrics used were average workplane DPF and DPF at individual workstations. Although the various DPF measures were reliable tools for calculating quantity of daylight illuminance, they proved less reliable indicators of user perception of quantity of daylight.

Some 40% of users in rooms with windows thought that the majority of light on their workstations was daylight, falling to 7% in windowless spaces. Even on workstations where average DPF was above 1.5% only 33% of users regarded daylight as the main source. Installations with or without windows differed significantly in terms of perceptions of amount of daylight and dissatisfaction with daylight, but not for amount of, or dissatisfaction with, total amount of light. Given the predominance of electric lighting and the small windows this is not surprising. Comparison of the results on questions on lighting quality with those described in Reference 3 is interesting. In terms of liking the visual environment the present results agree with the previous study for rooms with windows. For windowless rooms the results are markedly worse suggesting that a view of even distant windows has a more beneficial effect on perceptions of lighting quality than the output devices. About one quarter of users could detect diurnal variations in windowless rooms, presumably by changes in brightness of the guide output devices. The responses to questions on external view, detection of weather and diurnal variation in windowless spaces further confirms that TDGS are not as effective as windows in providing these, and that view out is important. The majority of users were satisfied with brightness conditions but the number reporting the scene too dim was greater than those reporting too bright. The mean assessments were low in the large windowless rooms but not those with windows. Thus despite their inability to contribute markedly to surface brightness the absence of windows appears to adversely influence perception of brightness. There are few reported problems with glare which is consistent with both the low levels of illuminance and the type of lighting equipment used.

The investigation of user response to different output device grid configurations was inconclusive. Both were only liked by 30% of respondents and the only major difference, that of perception total illuminance, may be accounted for by differences in workstation illuminance. Generally square output devices were rated more favourably than circular with total workstation illuminance being perceived to be higher for similar physical conditions. This may be because the square device resembles a luminaire. Perception of the main ‘components of daylight’ was studied with increasing DFP. Unsurprisingly perception of amount of daylight increases, as does assessment of colour, evenness of the lighting and detection of weather changes. There is no improvement in perception of external view or diurnal variation with increasing DPF suggesting that even the largest TDGS aperture areas are inferior to windows in these respects. The study of similar areas equipped or otherwise with TDGS showed significant differences in physical conditions but, with one exception, no differences in user perception of quality issues. The addition of TDGS in a deep plan office thus appears to only marginally increase user perception of lighting quality.

The results so far confirm that user perception of lighting quality in TDGS improves with increasing daylight penetration. It is hypothesised that a DPF approaching 2% may provide a ‘well day-lit space’ corresponding to that provided by 2% daylight factor using conventional glazing. This study provides the opportunity of investigating what this proposition would mean in practice for a large open plan office. In Building 22 the actual configuration is a regular array of 40 No. 500 mm diameter output devices at an SHR of 4.3 giving an average DPF of 0.6%. A 2% average DPF would require a regular array of 80 No. 650 mm diameter devices at SHR 1.8. These would occupy nearly 10% of the roof area and may have constructional, structural or environmental implications for the building. Furthermore office buildings tend to be designed with suspended ceiling heights of the order to 3 m. This imposes a limit on the DPF that can be achieved if the SHR of the output device is constrained by, say, a luminaire grid or structural requirements. If Building 22 were to be relit using a grid spacing of 1.25 for both lighting devices there would be about 100 unit of each. Using 300 mm diameter output devices the DPF would be 0.7%; for 500 mm diameter 1.6%; and for 650 mm diameter 2.8%. Under these circumstances the capital cost of a suitable TDGS is likely to be several times that of electric system and raises the question of whether the benefits of the daylight delivered by the system are sufficient to offset this.

4. Conclusion

The TDGS studied in this work with their dominant electric lighting and low daylight penetration represent a lost opportunity for their designers. Whilst it is clear that TDGS can provide daylight in deep open plan spaces, users appeared reluctant to regard it as such. The results suggest that TDGS, of whatever configuration, are considered inferior to windows in delivery of most aspects of quantity and quality of 'daylight' although satisfaction of some aspects improves with increased average DPF. There is a case for including windows – however small – in offices lit using TGDS to aid user interaction with the exterior.

It is pertinent to pose the question – what is the worth of the TDGS in offices as presently configured? Whilst it is clear that open plan offices with windows and TDGS perform better than those without windows there is not sufficient evidence as to whether deep plan offices with TDGS perform better than those without. More work is needed on this. The popularity of daylight is evident and user perception of this, and its benefits, seems to increase with increasing daylight penetration. This work offered no opportunity to establish if DPF of the order of 2% would produce a 'well daylight space' but it is clear that the practicalities of providing this using TDGS are not trivial. Before the question can be finally answered the benefits of using TDGS in terms of delivery of daylight and any energy savings need to be balanced against long term costs of such systems.

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Paper presented as Invited Lecture at the International Conference ILUMINAT 2007 Cluj-Napoca, Romania, 31 May - 1 June 2007

LIGHTING
– ENERGY CONSUMPTION AND ENERGY EFFICIENCY

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The IEA Annex 45 – Energy Efficient Electric Lighting for Buildings is an international co-operation project on energy-efficient lighting. Currently there are 20 participating and corresponding countries and 37 organisations in the project. The objectives of IEA Annex 45 are to identify and accelerate the use of energy-efficient high-quality lighting technologies and their integration with other building systems, to assess and document the technical performance of existing and future lighting technologies, as well as to assess and document the barriers preventing the adoption of energy-efficient technologies, and to propose means to resolve these barriers.

1. Introduction

International Energy Agency (IEA) is an intergovernmental body committed to advancing security of energy supply, economic growth and environmental sustainability through energy policy co-operation. IEA has Implementing Agreements (IA) to organize research. One of these IAs is Energy Conservation in Buildings and Community Systems (ECBCS). The function of ECBCS is to undertake research and provide an international focus for building energy efficiency. The tasks in ECBCS are undertaken through a series of Annexes that are directed at energy saving technologies and activities that support their application in practice. The results are also used in the formulation of energy conservation policies and standards.

The Executive Committee of the ECBCS program established a new Annex in June 2004 called Energy Efficient Electric Lighting for Buildings. Professor Liisa Halonen from Lighting Laboratory of Helsinki University of Technology was elected for the Operating Agent of the Annex 45.

2. Lighting energy and efficiency

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. In 2005 the energy consumption of grid-based electric lighting was 2 650 TWh worldwide, about 19 % of the total global electricity consumption. That means 133 petalumen-hours (Plmh) of electric light was used, an average of 21 megalumen-hours/person. However the use of this light is very unevenly ditributed. In addition 55 billion litres of gasoline and diesel are annually used to operate vehicle lights. More than one-quarter of world's population uses liquid fuel (kerosene) to provide lighting. [1] The global lighting electricity use is distributed approximately 28 % to the residential sector, 48 % to the service sector, 16 % to the industrial sector, and 8 % to street and other lighting. For the industrialized countries national lighting electricity use ranges from 5 % to 15 %, while in developing countries the value can be as high as 86 % of the total electricity use. [2]

More efficient use of electric lighting would limit the rate of electric power consumption increase, reduce the economic and social costs resulting from constructing new generating capacity, and reduce the emissions of greenhouse gases and other pollutants. At the moment fluorescent lamps dominate in office lighting. In domestic lighting the dominant light source is still the more than a century old, inefficient incandescent lamp. The aspects to consider in providing efficient lighting are energy savings, daylight use, individual control of light, quality of light, emissions during life cycle and total costs.

The building sector in the EU consumes over 40 % of energy use in EU and is responsible for over 40 % of its carbon dioxide emissions. Lighting is a substantial energy consumer, and a major component of the service costs in many buildings. The percentage of the electricity used for lighting in European buildings is 50 % in offices, 20-30 % in hospitals, 15 % in factories, 10-15 % in schools and 10 % in residential buildings [3]. To promote the improvement of the energy performance of buildings within the community, the European Parliament has adopted the Directive 2002/91/EC on the energy performance of buildings. [4]

The average lighting system efficacy by region is estimatd to be 50 lm/W in North America, 54 lm/W in Europe, 65 lm/W in Japan, 49 lm/W in Australia and New Zealend, 58 lm/W in China, 43 lm/W in former Soviet Union and 43 lm/W in the rest of the world.

3. Trends in energy efficient lighting

Electric light is provided as a result of combination of lighting equipment. A modern lighting system requires light sources, ballasts, luminaires and controls. Part of the power input to the lighting unit is transformed into light, while the rest is considered as loss. Energy is lost in lamps, luminaires and ballasts in the form of heat. The saving of lighting energy requires the use of energy efficient components as well as the application of control, dimming, and the use of daylight.

35 % improvement has been reported in efficiency of T5 fluorescent lamp using mirror louvre fixture over an equivalent T8 mirror louvre fixture when using a high-frequency ballast and a standard aluminum reflector. The corresponding improvement in efficiency for a luminaire of the same type with conventional ballast was about 65 %. [5]

In IEA Annex 45 one objective is to develop a lighting control system with high level of intelligence and multiple levels of control that learn and adapt to user's preferences and behavior. The usage of wireless sensors and actuators is a key component for new lighting control systems. It is also possible to integrate such a system into existing buildings. On the other hand is it impossible to realize an intelligent lighting system without a lot of sensors and actuators to capture and control the environment.

The Directive 2000/55/EC gives energy efficiency requirements for ballasts for fluorescent lamps. The maximum power of ballast-lamp circuit, for example, of a 36 W fluorescent lamp should be less than 45 W after 21 May 2002 and less than 43 W after 21 November 2005. [6]

High pressure discharge lamps are very energy-efficient lamp types. Their small discharge tube allows an efficient reflector design for luminaires so that the luminous flux from the luminaire can be distributed effectively in the room. Typically, it takes 3 minutes to reach 80% of the nominal luminous flux of a high pressure discharge lamp. For automotive lamps, this time has been reduced to 3 seconds already [7]. At present, high pressure discharge lamps cannot replace other lamp types.The reasons are in the start performance and in restricted dimming performance. Research on the interaction of ballast electronics and high pressure discharge lamps may significantly improve the performance of this lamp type.

LEDs (Light Emitting Diodes) are new alternative light sources, which are foreseen to revolutionise the lighting technology in the near future. According to Agilent Technologies the lumens/package value of red LEDs has been increasing 30 times per decade whereas the price is decreasing 10 times per decade [8]. The use of LED based lighting could decrease the lighting energy consumption by 50 % by 2025 [9]. The future entrance of LEDs in the lighting market is dependent on improvements in conversion efficiency and optical power per package. Although most of the high-power LEDs (HP-LEDs) nowadays convert between 15 to 20% of the input power into light, their efficiency potential is far better. In fact the best AlInGaP (aluminum indium gallium phosphide) red LED and InGaN (indium gallium nitride) green and blue LEDs can have internal quantum efficiencies which can reach almost 100% and 50%, respectively. To achieve external quantum efficiencies close to that magnitude, the light extraction has to be improved. By allowing more photons to escape from the LED chip without been absorbed by the surrounding structure, is one of the main design challenges which has to be addressed in order to increase the device conversion efficiency and the radiant power per device. New technologies have been developed in order to address this issue. The most promising one is the use of quantum dots or nanoparticles. Quantum dots are characterized by having a large absorption spectral range characteristic and a tunable spectral emission. This makes them ideal to substitute conventional and inefficient phosphors used today in white LEDs. However, improvements have to be done especially in the quantum efficiency of quantum dots.

The importance of LED lighting was acknowledged this year also by the Millennium Technology Prize Foundation. The 2006 Millennium Technology Prize, the world's largest technology award, was awarded to Professor Shuji Nakamura for his invention of the blue LED. [10]

4. IEA Annex 45

4.1 Objectives

The goal is to identify and to accelerate the widespread use of appropriate energy efficient high-quality lighting technologies and their integration with other building systems, making them the preferred choice of lighting designers, owners and users.

The aim is to assess and document the technical performance of the existing promising, but largely underutilized, innovative lighting technologies as well as future lighting technologies and their impact on other building equipment and systems (ie: daylighting, HVAC). These novel lighting system concepts have to meet functional, aesthetic, and comfort requirements of building occupants.

The aim is to assess and document the barriers preventing the adoption of these promising existing and future technologies (ie: technical, economic, risk factors, resistance to change, legislative, etc.) and propose means to resolve these barriers.

4.2 Structure

The Annex 45 will run between 2005 and 2008. The work of Annex 45 is divided to four Subtasks.

- Subtask A Targets for Energy Performance and Human Well-being
- Subtask B Innovative Technical Solutions
- Subtask C Energy-efficient Controls and Integration
- Subtask D Documentation and Dissemination.

Subtask A: Targets for Energy Performance and Human Well-Being

The objective are to document the effect of design and targets for energy use, lighting quality and human well-being. To propose an upgrade of lighting recommendations and codes to improve the energy performance of indoor lighting installations.

The performance criteria include the spectral, electrical and user related issues. The energy criteria include energy efficiency, life cycle energy considerations, maintenance and operation. The economical criteria include cost of devices and of application.

Subtask B: Innovative Technical Solutions

The objective is to identify, assess and document the performance, energy and economical criteria of the existing promising and innovative future lighting technologies and their impact on other building equipment and systems. The purpose is to reduce the energy use of buildings by investigating the saving potential by comparing the existing and future technologies and by applying information on concepts, products and lighting solutions. The technical solutions cover power supply, light sources, luminaries and concepts of controls.

Subtask C: Energy-Efficient Controls and Integration

The Subtask C focuses to optimal use of controls that enables energy savings whilst the user (occupant, facility manager, operation and maintenance team…) has the possibility to modify the electric lighting according to personal needs and preferences, within acceptable building operative requirements. Subtask C gives guidelines to designer, installers, manufacturers to achieve the above- mentioned aim.

Subtask D: Documentation and Dissemination

The objective of Subtask D is to improve current lighting practices in a manner that accelerates the use of energy efficient products, improves overall building performance and enhances the occupants' environmental satisfaction. The objective of Subtask D is to compile and widely disseminate the Annex research results and to identify the means to influence the energy policies and regulations in order to promote the use of energy efficient lighting. The main deliverables of the Annex will be Guidebook on Energy Efficient Electric Lighting for Buildings, semi-annual Newsletter, seminars and a website (http://lightinglab.fi/IEAAnnex45).

4.3 Management of the Annex 45

The Annex is managed by the Operating Agent with the assistance of the Subtask Leaders. Currently there are 20 participating and corresponding countries and 37 organizations in the Annex 45.

More information of the Annex can be found from the Annex web-site: http://lightinglab.fi/IEAAnnex45 or from Liisa Halonen (liisa.halonen@tkk.fi) or Eino Tetri (eino.tetri@hut.fi) from Helsinki University of Technology.

5. Energy savings – Case office lighting

Measurement of the power used by the office rooms of HUT Lighting Laboratory in Finland was done during all four seasons of the year and the annual energy consumption was calculated based on the measured values. The Lighting Laboratory building was built as a demonstration building for lighting research. The rooms of the building are equipped with the variety of lighting control systems including both old manual system and newest technologies for the integration of artificial and natural lighting.

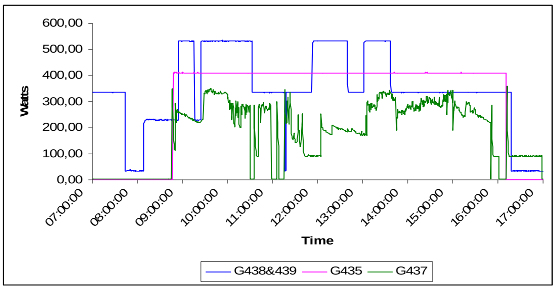

Figure 1 Power consumption curve for rooms G435, G437, and G438&439

Three sets of rooms (G435, G437, and G438&439), each with different lighting control system was chosen for the measurement and assessment. All the rooms were equipped with T5 (35 W and 28 W) fluorescent lamps (CCT = 3000, and CRI>80). Room G435 has only manual up/down lighting control system whereas room G437 has a constant light control with a photosensor, rotary control switch and occupancy sensor. Only occupancy sensor control was used in the rooms G438&439. As seen in the power curve (Figure 1), the room G435 uses full installed power all the time. Rooms G438&439 also use full installed power, but only when the rooms are occupied. Due to the combination of dimming according to daylight and occupancy control, the power curve of room G437 is changing over short intervals. It uses full installed power only when the daylight is completely unavailable.

Table 1 Measured values of illuminance, glare rating, installed power, and energy consumption

Rooms	Average Illuminance in lx		UGR	W/m^2	kWh/m^2
	Working plane	Floor			
G435	575	380	11	14,1	33
G437	665	390	16,4	16,9	20
G438&439	704	501	11,5	16,3	24

UGR = Unified Glare rating
W/m^2 = Installed power for lighting per square metre of room, in W/m^2
Wh/m^2 = Annual energy consumption per square metre of the room, in kWh/m^2

Room G437 has highest (16,9 kW/m^2) and the room G435 the lowest (14,1 kW/m^2) installed power for lighting, but due to daylight based dimming and occupancy control in room G437, it consumes the least energy (20 kWh/m^2 per annum) compared to 24 kWh/m^2 of rooms G438&439 (only occupancy control) and 33 kWh/m^2 of room G435 (manual control). On the other hand, as seen in the Table 2, the working plane illuminance in the room with high energy consumption is lower compared to the other rooms. The energy consumption for rooms except the one with manual control is well below the average annual energy use for lighting in Finnish offices, which is 31 kWh/m^2 (Korhonen et al., 2002). The average working plane illuminance levels of all these rooms (Table 1) are higher than the current recommendation level (Table 1), so there is still possibilities to reduce the annual energy consumption level below 20 kWh/m^2 without compromising lighting quality.

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LUMINANCE VARIATION ASSESSMENT IN ROAD NOCTURNAL LIGHTING

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The visual comfort and the security of the road traffic participants depend on many factors especially during the night. The experts use some variables in order to assess the disability and discomfort glare phenomena, being just reminded the flaring and flicker phenomena. The visual task perception may be considered in a certain point and at a given moment, but not only the subject changes the position related to the environment and the lighting system but also the other vehicles that take part to the traffic. Therefore, a variation of the subject visual perception occurs, leading consequently to the flicker phenomenon. The flicker produced by the visual perception variation owing to the shifting on the road of both the subject and the vehicles has to be evaluated in order to prevent the induced tiredness state. If the glare assessment corresponds to the visual perception at a given moment, the flicker evaluation corresponds to the variation in time of the visual perception of the subject participating to the traffic. The purpose of this paper is to apply the estimation methods of the flicker indicators to the road lighting systems, making experimental determinations and computer aided analysis in order to justify the relevance of this task. The estimation of the tiredness estate correspondent to the flicker may be therefore attached to the aspects referring to the lighting systems quality and the road traffic safety.

1. Introduction

In order to increase the road traffic safety and to make flatter the power systems load characteristics, some countries, like, for example, Belgium, have extended the roads and highways nocturnal lighting. This fact led the drivers to the finding that the tiredness state is increased and installed earlier than on the roads without nocturnal lighting. The only plausible explanation of the tiredness increase, based on the repeated crossing of the drivers of some visual fields un-uniform from the lighting point of view, is the appearance of the flicker phenomenon. Because there are defined indicators and assessment methods for the flicker produced by the voltage fluctuations, including also the admitted limits, the only problem is to adapt the relationships and the estimation methods of the flicker to the lit roads traffic.

2. Theoretical basis

2.1. Glare and tiredness evaluation

Taking into account the cars great speed during their traveling, the physiological and psychological glare problem is very important in order to provide maximum security conditions to the traffic. The disturbing sensation, consisting in a reduction of the visual task contrast versus the background, leads to the decrease of the correct perception capacity of the elements from the visual field.

The concern to evaluate the visual field effects over the sight and the human psychic is concretized in a group of photometrical variables, more or less elaborated.

The discomfort glare evaluation in the visual field is made through the *TI* (threshold increment) index, given by the empirical relationship:

$$TI = 65\frac{L_v}{L_m^{0,8}}\text{ , \%,} \qquad (1)$$

where L_m is the average luminance of the road, the observer being located on the centre line of a lane, and L_v – the veiling luminance, giving the virtual image of the light sources on the observation direction.

The psychological glare represents a very important aspect of the visual comfort but also of the traffic security. The multitude of factors that determine the psychological or disability glare phenomena is included in the calculus relationship of the **glare control mark** *G* (CIE 31-1976):

$$G = 13.84 - 3.31\lg I_{80} + 1.3\left(\lg\frac{I_{80}}{I_{88}}\right)^{1/2} - 0.08\lg\frac{I_{80}}{I_{88}} + 1.29\lg F + 0.97\lg L_M + 4.41\lg h' - 1.46\lg p + c, \qquad (2)$$

where I_{80}, I_{88} are the maximum luminous intensities for height angles $\gamma=80^0$, respectively $\gamma=88^0$ and azimuth angles $C = 0...20^0$, in cd; *F* - the luminaire lighting area, projected under an angle of 76^0 versus the vertical, in m^2; L_M – the average luminance of the road, in cd/m^2; *h*' - the vertical distance between the eye level and the luminaire; *p* - the number of luminaires per kilometer, in km^{-1}; *c* - correction factor according to the lamp type (colour), having the following values: *c*=0.4 for low pressure sodium-vapour lamps, *c*=0.1 for high pressure sodium-vapour lamps and *c*=-0.1 for high pressure mercury-vapour lamps.

We have to remark that both specific variables of the glare have an empirical character, so they represent efforts to detect as much as possible the real phenomenon. However, the issue is to evaluate a luminous sensation at a given moment and not to estimate a sensation accumulated in time. In fact, the variable *p* representing the luminaires number per kilometer appears only in relation (3), but without the *t* variable, the glare control mark *G* cannot detect the tiredness produced by the flicker.

2.2 Flicker phenomenon

2.2.1. Definition and causes

According to the standard [6], the flicker is defined as the impression of instability of the visual sensation, produced by a luminous stimulus whose luminance or spectral distribution is fluctuant in time. The coordinates of this definition are very important in order to understand how to apply the analytical methods of the flicker evaluation. The point is that we have to do with the instability or variability of the visual sensation; the term of fluctuation in time outlines the periodical character of the visual sensation instability, with periodicities in the specific range of the fluctuations.

The reasons of the instability or the visual sensations variability may be more than those included in the definition from the mentioned standard, meaning that the subject is stationary in a visual field where some variable luminous stimulus exists. The periodical variations of the visual sensations can be induced by the following causes:

- **luminous fluxes fluctuations**, emitted by the lighting systems due to either the voltage fluctuations or the flaring of some lighting sources (the flaring can be normal, if the role of the lighting sources is to emit an intermittent luminous flux or faulty ones, if the ignitions or the extinctions of the lighting sources are due to the abnormal functioning of the electrical circuits);

- the **fluctuation in time of the light spectral composition** due to either the periodical variation of the lighting sources spectral distribution or the colour variation of the perceived objects or, finally, the observer's movement with a given speed in a visual field where lighting sources having different colour temperature exist;

- the **human subject's movement** in a visual field, variable from the photometric variables point of view, but which repeats itself in the space;

- the movement of some successive lighting sources (given by the cars) versus the human observer.

The visual sensation instability represents only the starting point of the flicker appearance. As the evaluation methods of some flicker specific variables show, the point is to determine the cumulated effect of these instabilities, i.e. the tiredness sensation resulted from the accumulation of both the momentary discomfort and the eye continuous re-adaptation effort.

2.2.2. Indicators

The flicker occurring due to the voltage fluctuations is estimated using the following **indicators**: the fluctuations amplitude, the flicker dose and the flicker severity [3, 6, 7]. Because the computation methods of the indicators are relatively well elucidated and even standardized, the only problem is to adapt these methods to the assessment of the flicker induced by the other causes, not by the voltage fluctuations.

The relation between the voltage fluctuations and the discomfort produced to the human sight is due to the luminous flux variations of the light sources. It is known that the luminous flux variations of the lamps having the frequency of 100 Hz (the lamps fed at industrial frequency) do not produce discomfort to the human sight. If the frequency of the luminous flux variations decreases, the eye becomes sensible, but only if the amplitude of these variations exceeds a certain **threshold**.

By definition [2, 6], the fast variations or **the voltage fluctuations** represent variations of the RMS or pick values of the voltage waves, in the interval of ±10%, produced in the range of (0.003 ÷ 5) Hz (periodicities between 40 ms and 5 min).

a) Voltage fluctuations amplitude

If U_j and U_{j+1} are two consecutive values of the voltage amplitude, determinable from an oscillogram, a registering or a data acquisition, the voltage fluctuation amplitude is defined with the relationship

$$\delta U_j = \frac{|U_j - U_{j+1}|}{\sqrt{2} U_n} \qquad (3)$$

where U_n represents the RMS value of the corresponding rated voltage. It has to be outlined that the voltage fluctuation amplitude is a positive variable. Moreover, we can specify that two or more voltage variations produced in a relatively short period (below 30 ms) may be considered as a single variation.

Important remark: in fact, if the mechanism of the evaluated process is taken into account, the relation (3) is not correct because neither the eye nor the human brain are provided with adjustments of the visual perception corresponding to a rated voltage or, generally, to a reference situation. The analytical modelling of the visual perception relative variation should impose that in relation (3) denominator should be the variable U_j, so the visual perception variation should be relative to the visual sensation that is anterior to the appearance of the variation to which the human eye has already adjusted.

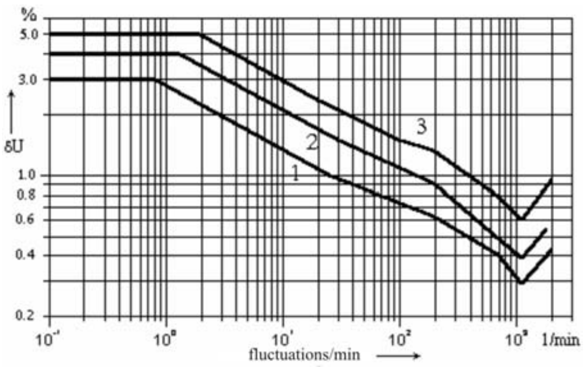

Figure 1 Voltage fluctuations amplitudes, maximum admitted in the LV public networks, versus the fluctuations number in a minute:
1 - according to the CEI norms;
2 - for incandescent lamps;
3 - for fluorescent lamps.

The voltage fluctuations amplitudes, maximum admitted in the low voltage (LV) public networks, are presented in Figure 1 related to the fluctuations number in the time unit.

b) Flicker dose

It has been experimentally established that the voltage fluctuations influence over the sight depends not only on the frequency and amplitude, but also on the shape of the modulating signal. The **minimum** of the **sensitiveness threshold** is for a sinusoidal signal for the voltage modulating, having a frequency of about 10 Hz and a relative amplitude of approximately 0.3%.

The evaluation of the voltage fluctuations influence is made in accordance with the **cumulative principle,** based on the recording of the tiredness accumulated by the eye up to the dose where work becomes impossible. The judgement is based on the equivalence between a fluctuation of f_i frequency and δU_{fi} amplitude with a fluctuation having 10 Hz as reference frequency and the relative amplitude in order to determine an identical sensation of uneasiness.

The flicker dose is defined by the relationship

$$\varepsilon_F = \int_0^{T_0} \left(\delta U_{10}\right)^2 \cdot dt, \ (\%)^2 \text{ min}, \quad (4)$$

where T_0 represents the perturbation assessment (observation) period. The flicker dose expresses the total uneasiness that an eye feels during T_0. The dependence of the periodical flicker dose versus its duration is presented in the Figure 2.

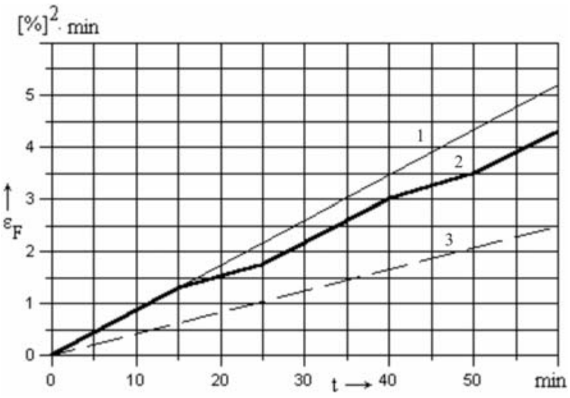

Figure 2 Dependence of the periodical flicker dose versus the flicker duration:
1 - disturbing flicker (0.3% at 10 Hz);
2 - admitted flicker dose;
3 - imperceptible flicker (0.2% at 10 Hz)

c) Flicker severity

The correct modelling of the reactions of an observer to any voltage fast variations, irrespective to what shape and frequency could have the modulating signal, may be realized through the **statistical method** (UIE proposal), by evaluating the flicker severity. The statistical method for the fluctuations effects evaluation is based on the representation of the cumulated probability function versus the fluctuations amplitude.

For short periods of time, the flicker severity is calculated in accordance with the relationship:

$$P_{st} = \sqrt{\left(k_{01}\overline{\delta U_{01}} + k_1\overline{\delta U_1} + k_3\overline{\delta U_3} + k_{10}\overline{\delta U_{10}} + k_{50}\overline{\delta U_{50}}\right)}\ , \quad (5)$$

where the variables marked above with a line represent average values; their calculus relations are known and the coefficients k_{01}, k_1, k_3, k_{10} and k_{50} have determined values [6, 7].

If the working cycle of the receiver or end-user who produces the flicker is longer (about hours), it is recommended to make the flicker severity calculus for a **long period**, according to the relationship

$$P_{lt} = \left(\frac{1}{N}\sum_{i=1}^{N} P_{sti}^3\right)^{\frac{1}{3}}, \quad (6)$$

where P_{sti} are consecutive values of the flicker severity, recorded on short periods of time (i=1, 2, 3,…, N), and N - the number of the short periods of time included in the long one. A **two hours** period is considered to be long enough for the calculus of this indicator. The admitted limits of the flicker severity are given in [6, 7] related to the voltage level of the electrical network.

2.3. The flicker in the road lighting

2.3.1. Luminance fluctuations amplitude

Because the flicker phenomenon refers in fact to the discomfort produced at the human brain level through the periodical variation of the visual perception, the reasons that lead to such a variation have to be emphasized. If in the case of interior lighting one of the causes may be the variation of the voltage RMS value, in the case of nocturnal road lighting the flicker generating cause could be as well the movement of the drivers in an un-uniform field of luminances or even the relative movement of other vehicles in comparison with a considered observer.

A direct connection can be made with the calculus relation of the voltage fluctuations amplitude and further on with the relation of the flicker dose and flicker severity calculus because, in fact, the voltage relative variation renders exactly the relative variation of the luminances. Consequently, by similarity to the voltage fluctuations amplitude, the **amplitude of the luminance fluctuations** may be defined as follows:

$$\delta L_{vj} = \frac{|L_{vj} - L_{vj+1}|}{L_{vj}}\ 100,\ \%, \qquad (7)$$

where L_{vj} represents the luminance to which the eye is adapted in the moment t_j and L_{vj+1} – the luminance to which the eye is to adapt in the moment t_{j+1}. In fact, for the usual speed of the vehicles movement could matter just the fact that the adaptation to luminance of the eye varies between a minimum and a maximum value. If the maximum and minimum luminances are repeated with absolute identical values in the frame of the lighting system, the fluctuations amplitudes from maximum to minimum, respectively from minimum to maximum, will not be identical because of the variable to which the reference of the absolute variation is made.

Therefore, the luminance fluctuation amplitude when the observer is passing from the point of maximum luminance L_M to the point of minimum luminance L_m is

$$\delta L_{Mm} = \frac{|L_M - L_m|}{L_M}\ 100,\ \%, \qquad (8)$$

while in the second case, assuming the passing from the minimum luminance point to the maximum luminance one, the luminance fluctuation amplitude value will be

$$\delta L_{mM} = \frac{|L_m - L_M|}{L_m}\ 100,\ \%, \qquad (9)$$

superior to the value given by the relation (8).

Further on, the luminance fluctuations frequency will be determined according to the mentioned causes that produce the flicker.

2.3.2. The frequency of the luminance fluctuations owed to the lighting system

The road lighting systems are dependant on the emplacement modalities of the luminaires, the luminaires types and the characteristic variables of their emplacement.

For an observer who crosses the road following a certain direction results an un-uniform spatial distribution of the luminances, even if the luminaires producers and the lighting systems designers are professional ones. The minimum and maximum values between which the luminances perceived by the observer are situated and the variation profile of the luminances are very important when a vehicle is travelling on a road with nocturnal lighting.

Considering that the distances between the consecutive points of maximum luminances are equal with those between the consecutive points of minimum luminance and equal as well with the distance between two poles on the same side of the road, the luminance fluctuations frequency is

$$f_s = \frac{v_s}{d},\ \text{Hz}, \qquad (10)$$

where v_s is the vehicle (observer) speed related to the lighting system, and d - the distance between the supporting poles af the luminaires, situated on the same side of the road.

A nomogram for the frequency determination of the luminance fluctuations caused by the observer movement related to the lighting system in accordance with the relation (10), is presented in the Figure 3.

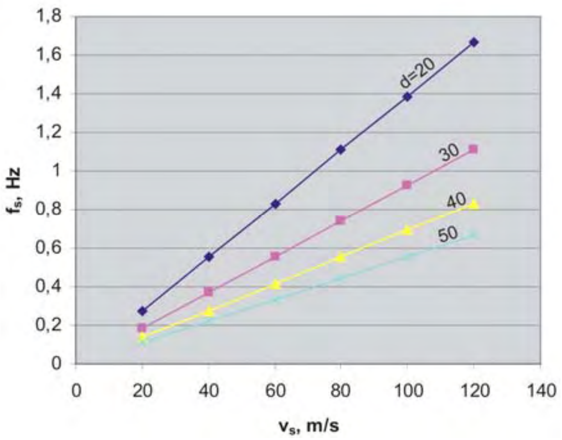

Figure 3 Frequency of the luminance fluctuations caused by the observer movement in comparison with the lighting system (d, m)

It has been found that for the ranges of the considered calculus variables the luminance fluctuations frequencies result in the interval (0.1÷1.8) Hz.

2.3.3. Frequency of the luminance fluctuations owed to the traffic from the opposite sense

For the vehicles travelling on the opposite sense, the most unfavourable situation is for the adjacent lanes when a vegetation veil doesn't exist. There are situations in this case, too, when the opposite sense vehicle or vehicles affect the observer eye through maximum or minimum luminances, with a determined profile of the luminances variation.

The frequency f_c of the luminance fluctuations due to the traffic of the opposite sense vehicles is

$$f_c = \frac{v_s + v_c}{d_c} \text{ , Hz,} \qquad (11)$$

where v_c is the speed of the opposite sense vehicles, d_c - the distance between two successive vehicles which come from the opposite sense and v_s was previously specified.

The nomogram from the Figure 4 presents the dependence of the fluctuations frequency f_c in accordance with the relation (11).

As it can be noticed, the frequencies of the luminance fluctuations due to the opposite sense traffic result in the interval (0.1÷3.5) Hz for the ranges of the considered calculus variables.

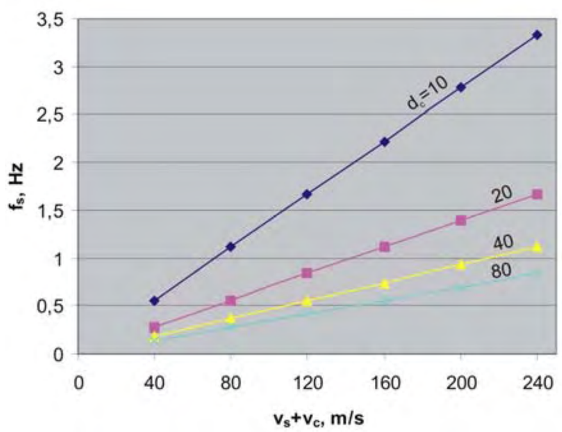

Figure 4 Frequencies of the luminance fluctuations owed to the opposite sense traffic (d_c, m)

2.3.4. Frequency of the luminance fluctuations due to the same sense traffic

In this case the subject, being behind the steering wheel of a vehicle that travels on a marginal lane, receives the rear images of the vehicles which overtake him. Even if the luminances of the vehicles stop lights have low values, the contribution of their variation over the total flicker cannot be neglected in the absence of an informative evaluation.

Similar to the relation (11), the frequency f_a of the luminance fluctuations due to the same sense vehicles that overtake the subject on an adjacent lane may be determined with the relationship

$$f_a = \frac{v_a - v_s}{d_a} \text{ , Hz,} \qquad (12)$$

where v_a represents the absolute speed of the same sense vehicles which overtake the observer vehicle, d_a - the distance between two successive vehicles travelling in the same sense, and v_s keeps the previously signification.

The nomogram for the determination of the luminance fluctuations frequency caused by the travelling of the vehicles that overtake the observer vehicle is presented in Figure 5. As it can be noticed, the frequencies of the luminance fluctuations result too in the interval (0.1÷3.5) Hz for the ranges of the considered calculus variables.

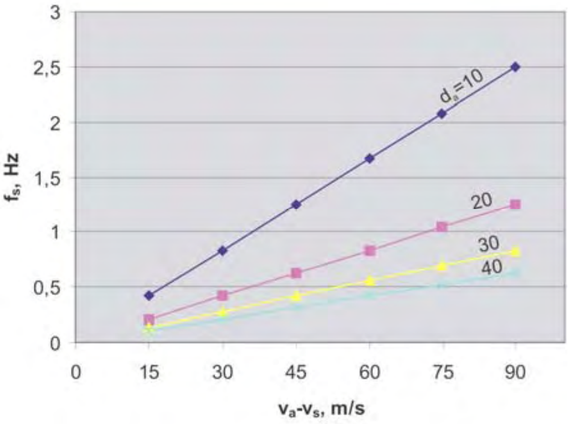

Figure 5 Luminance fluctuations owed to the same sense vehicles (d_a, m)

3. Results

3.1. Luminance fluctuations due to the lighting system

The luminance-meter Minolta LS-100 has been used for the luminances measuring. A lighting system considered as characteristic for the internal roads was chosen as follows: the roadway width l_0=14 m, with two lanes on each direction; the distance between the poles d=33.3 m; the luminaires mounting height h=9.4 m; the luminaires type as Onyx 2N, with SON T 250 W lamps.

The results of the luminance measurements performed along the longitudinal axis of the first lane are presented in Figure 6. The height of the luminance-meter objective has been established at 1.1 m above the street plane, in accordance with the height of the driver's eyes when sitting in the vehicle. The focusing ring of the apparatus has been oriented to the point from the roadway situated 60 m ahead.

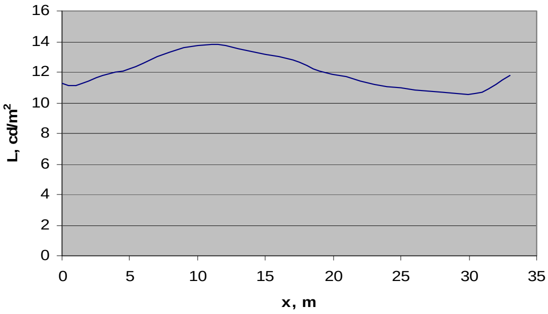

Figure 6 Luminances profile along the longitudinal axis of the first lane

The following values of the luminance fluctuations amplitudes due to the lighting system result according to the measurements:

$$\delta L_{mMs} = 30.2\ \%;\ \delta L_{Mms} = 23.2\ \%.$$

The admitted amplitudes of the fluctuations, determined in accordance with the CEI norms (fig. 1, curve 1) for the range of the fluctuations frequencies are situated between 2.8% at 0.2 Hz and 0.73% at 1.5 Hz. Consequently, in both studied cases the admissible amplitudes of the fluctuations are 8÷40 times exceeded.

3.2. Luminance fluctuations due to the opposite sense traffic

The measurements made for this case have taken into consideration the unfavourable situation considering the luminances perception from the reference point, situated on the roadway 60 m in front of the observer, when the vehicle is coming from the opposite sense on the adjacent lane. According to the real measurements, the observer position was adopted at 0.3 m left side versus the longitudinal axis of the personal vehicle lane and at 1,1 m above the street plane, considered as the eyes height. A two lanes roadway without lighting system has been chosen in order to reduce as much as possible the external influences. The measurements results, corrected with an error given by the measuring conditions, are presented in the Figure 7.

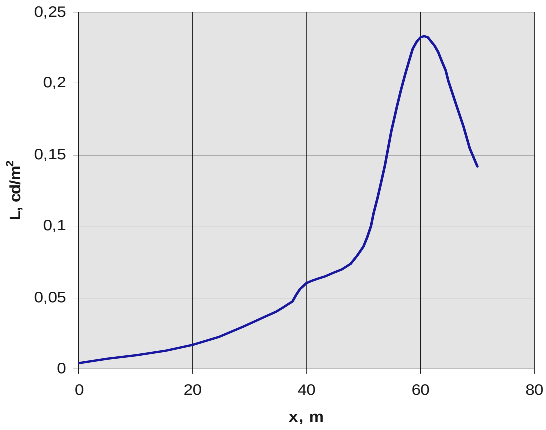

Figure 7 Luminances profile when a vehicle is approaching from the opposite sense

As it can be noticed, the maximum of the luminance received by the observer in the reference point is L_{Mc}= 0.232 cd/m^2, for a distance of 60 m versus the observer, so for the situation when the lights of the vehicle that comes from the opposite sense are in line with the target point. The luminance minimum (0.004 cd/m^2) is in the error range of the measurements, so we can consider L_{mc}=0. Consequently, the amplitudes of the luminance fluctuations due to the vehicle that comes from the opposite sense have the following values:

$$\delta L_{mMc} = 6.12\ \%;\ \delta L_{Mms} = 5.77\ \%\ .$$

At these calculations it has been considered that the luminances caused by the vehicle coming from the opposite sense are added with the average luminance of the road (an average luminance L_{med}=3.79 cd/m^2 was determined by modelling the lighting system on a computer).

The admissible limits of the admitted fluctuations, determined in accordance with the CEI norms (Figure 1, curve 1) for the range of the fluctuations frequencies pointed out in Figure 4, are situated between 0.95% at 0,2 Hz and 0.6% for the frequency of 1.5 Hz. Consequently, in both cases the admissible amplitudes of the fluctuations are 6÷10 times exceeded.

The images perceived by the observer in the previously mentioned conditions are presented in the Figure 8, for two distances: at 70 m (Figure 10, a) and at 20 m (Figure 10, b). The camera axis was focused on the reference point, situated at 60 m ahead of the observer, on the roadway.

a

b

Figure 8 Opposite sense vehicle, versus the observer situated at 3.2 m sideways and 1.1 m above the roadway, for the distances: a - 70 m; b - 20m

3.3. Luminance fluctuations owed to the same sense traffic

This case has taken into consideration the unfavourable situation of the vehicle that overtakes the observer on the adjacent left side lane. It was also considered that the observer perceives the luminance from the reference point, situated at 60 m ahead the observer, on the roadway.

The observer position was the same as in the case of the previous measurements (0.3 m left side versus the longitudinal axis of the personal vehicle lane and at 1.1 m above the street plane, considered as the eyes height); the other conditions were the same as well.

The measurements results, with the consideration of the error corresponding to the measurement conditions, are presented in the Figure 9.

The amplitudes of the luminance fluctuations due to the vehicle that overtakes the observer one, on the adjacent left side lane, have in this case the following values:

$$\delta L_{mMa} = 10{,}6\ \%;\ \delta L_{Mma} = 9{,}55\ \%,$$

At these calculations it has been considered that the luminance caused by the vehicle travelling in the same sense is added with the average luminance of the road. The admissible limits of the admitted fluctuations, determined in accordance with the CEI norms (Figure 1, curve 1) for the range of the fluctuations frequencies pointed out in Figure 5, are situated between 2.8% at 0.2 Hz and 0.7% for the frequency of 2.5 Hz. Consequently, in both cases the admissible amplitudes of the fluctuations are 3÷15 times exceeded.

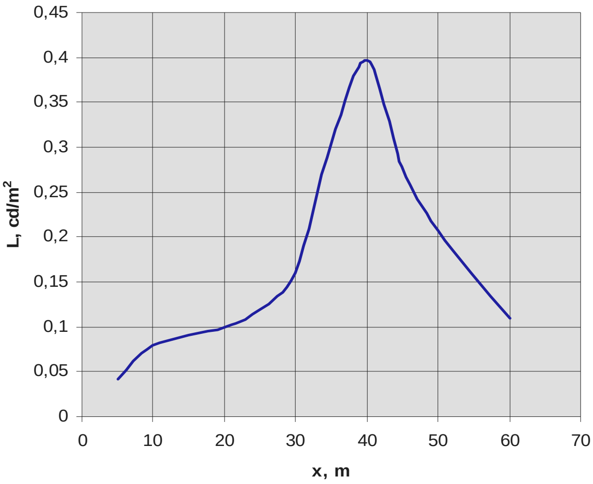

Figure 9 Luminances profile when a same sense vehicle overtakes the observer's one

4. Conclusions

The flicker designates the discomfort or tiredness sensation of a human subject, induced by the variation of his visual perception with frequencies included in the range (0.01÷50) Hz. In order to admit this notion in the frame of the road lighting, it is very important to emphasize that the discomfort is felt at the human brain level in accordance with the variation of the visual perception received by the eye and transmitted to the brain by means of the optic nerve.

The definition of the luminance fluctuations amplitude, given in this paper, takes into account the flicker phenomenon essence as it is internationally recognised. Three causes of the flicker have been pointed out for the roads, so the fluctuations frequencies have been determined for three types of flicker.

The results obtained according to the experimental data have emphasized important values of the luminance fluctuations amplitudes that exceed several times the admitted values adopted through standards.

Even if the measurements were organised so that the focusing ring of the luminance-meter be oriented to the reference point, situated 60 m ahead the observer on the roadway, it is important to remark that only the value of this luminance does not completely cover the visual perception of the human eye. This affirmation is supported by both the relation (1), that emphasizes the direct proportionality of the discomfort glare index *TI* with the veiling luminance L_v and the images presented in Figure 8 for the opposite sense vehicle. The relation (1) that defines the index *TI* describes and underlines the veiling luminance importance for the glare phenomenon. The same aspect is supported by the images from the Figure 8 and by the drivers experience as well. Consequently, the flicker phenomenon during the nocturnal traffic should be put in connection with the veiling luminance variations, too, or even with the variations of the glare indexes *TI* and *G*.

This study has to be continued up to the elaboration of some measures in order to limit the unfavourable consequences of the flicker due to the nocturnal traffic.

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RESIDENTIAL ENERGY EFFICIENT LIGHTING BY PROMOTING FLUORESCENT COMPACT LAMPS UNDER THE FRAME OF IEE PROGRAMME EnERLIn

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Keywords: Compact Fluorescent Lamps, Efficient Residential Lighting

1. Introduction

Both in European Union countries and in Romania, the residential sector represents an important potential for the reduction of energy consumption. The energy consumption in this sector is focused on lighting and domestic appliances and heating/air conditioning/hot water. The efficient use of electricity is still a neglected issue, with a lack of the necessary statistic data.

Market research has indicated that in order to substantially increase the use of CFLs in the residential sector, it is essential to develop and market attractive and good quality CFLs. The rate of the households owning a CFL covers the range from 0.8 units per household in Great Britain up to over 3 units per household in Denmark. Projects from the SAVE programme consider as a reasonable upper limit the use of up to 8 units per household. An analysis of the residential lighting, realized in 100 households in Denmark, shows a lighting consumption of between 5% and 21% of the total monthly electric energy consumption of the household and the use of 24% saving lamps – linear fluorescent lamps and compact fluorescent lamps. [1, 2] However, the same market analysis from Lighting Companies show that in Western Europe energy inefficient incandescence lamps (including halogens) still represent 30% of the sales [7].

2. EnERLIn - European efficient residential lighting initiative, supported by Intelligent energy Europe programme

The European Climate Change Programme (ECCP) identified residential lighting as an important area to CO_2 emission reductions. After a considerable number of promotion and rebate schemes, about 135 million CFLs are used today in European homes. However, only 30% of EU households have at least one CFL, with those households that own them having an average of three or four.

The residential lighting market is still dominated by inefficient Incandescent Lamps (GSL – General Service Lamps). The EnERLIn EIE SAVE program proposes to develop and validate robust scenarios for CFL promotional campaigns in European, national and regional levels. The European Union initiated numberless campaigns to promote compact fluorescent lamps with the purpose of increasing the market share of CFLs at 15%. The EnERLIn EIE SAVE program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting, and the ultimate objective of the program is to substantially increase the efficiency of residential lighting in a number of Member States. [9]

Objectives of the EnERLIn action. Improving the energy efficiency is a central theme of energy policy within the European Community, as indicated in the White Paper "An Energy Policy for the European Union", since improved energy efficiency meets the three goals of energy policy, namely security of supply, competitiveness and protection of the environment. Lighting represents an important part of building energy consumption in the EU – around 10% of the total electricity consumption, ranging from 5% (Belgium, Luxemburg) to 15% (Denmark, Netherlands, and also Japan). [6]. The residential sector represents 28% from the global electric lighting energy use. [7]

Overall electric appliances in households, industry and the tertiary sector represent 40% of the EU total electricity consumption, its generation being one of the most important sources of CO_2 emissions. Several EU and National Initiatives and Directives tented to promote energy efficient lighting for services sector buildings. These efforts can be judged as very successful because nowadays the CFL market share represents 20% of the global European market whereas the same figure in world scale is limited to 17%.

The ultimate objective of the EnERLIn program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries, and this can be done by offering them good arguments necessary to overcome the above cited barrier. To achieve successful residential market transformation we should promote that both light fixture outlets as well as design and specialty stores display their luminaires with CFLs (good and aesthetic ones) rather than GSL. At the same time the program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting. All the program objectives will lead to a higher market share for the most efficient CFLs and dedicated luminaires. The final beneficiaries will be end-users of equipment mainly in domestic sector.

Several European and national programs are devoted to the promotion of this type of lamps and try to limit the GLS use in households. These campaigns are today very efficient and the number of CFL sales increases in Europe rapidly. The average observed growth rate concerning CFL numbers is the order of 13.5% per year (in the order of 11.5% in western and 17% in

Eastern countries). It should notice that the annual growth rate of the global lighting industry is in the order of 0.8%. [9]

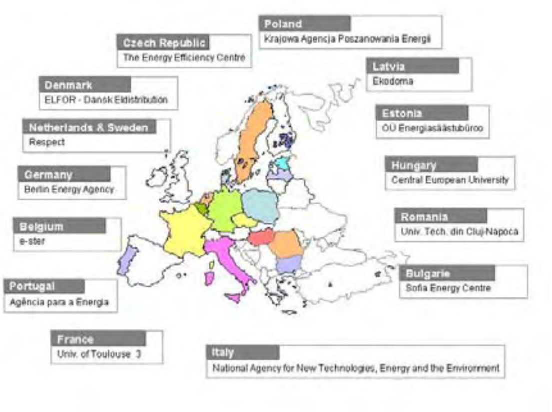

Figure 1 The EnERLIn consortium map

EnERLIn consortium

14 partners from 14 countries constitute the proposed consortium, covering a large part of the Europe form north to south and from east to west. This is an important issue; because, concerning lighting the reaction of the individual customers is quite different form a country to the other (north countries prefer low colour temperatures lamps, hot ambiance, and south countries are more sensitive to high colour temperatures, cold ambiance). The consortium includes western countries with high GDPs compared to eastern countries that they just integrated EU (Poland, Hungary, Czech Rep., Latvia and Estonia), and the newest EU countries (Bulgaria and Romania). The ENERLIN consortium is strongly cross-disciplinary including National or Regional Energy Agencies (ADENE, KAPE, ENEA, SEC, SEVEn, BE), one ESCO in Belgium, academic institutions (France, Hungary and Romania), a values-based consultancy focussing on sustainability (Respect) as well as independent consulting SMEs (Ekodoma, Energy Saving Bureau). Each partner has solid experience with EU projects (especially from DG TREN), and strong links with international organisms like CIE and projects like ELI, other European networks (COST-529) and programs (GreenLight). Some partners are quite influential for policy-making bodies in both national (regional) and European levels.

The **Romanian National Strategy in the energy efficiency field - 2004** underlines that the residential sector has a primary energy saving potential at 3.6 millions tones equivalent petrol through 6.8 million tones of the total final consumers; it means more than 50%. This potential can be capitalized by the rehabilitation of the buildings thermic insulation, the improvement of the heating and lighting systems and of the electric domestic appliances.

4. Analysis of electric lighting energy consumption in the residential sector in Romania

The statistic data [11] for the period 2000 – 2004 allow us to determine the variation of total household consumption, total number of household consumers, average consumption per household consumer, and of the specific consumption kWh/m^2 per year - Figure 2.

During November 2005 a preliminary study has been realized using feed-back reply forms concerning the usage degree of GSL and CFLs in households in Western Romania. We received 295 replies, namely

220 apartments (with 1–4 rooms - living room and bedrooms) and 75 houses (with 2–more than 7 rooms - living room and bedrooms). The light source equipment is presented in Table 1, and the average installed power - in Figure 3.

Table 1 Light source usage statistics for GSL and CFLs in Romanian households.

Household		**GSL**		**CFL**		**Installed power**
Type	No.	Units	Average	Units	Average	kW
Apartment	220	2624	11.98	367	1.67	0.770
Single-family house	75	1088	14.51	196	2.61	1.028
Total	295	3712	12.58	563	1.91	0.835

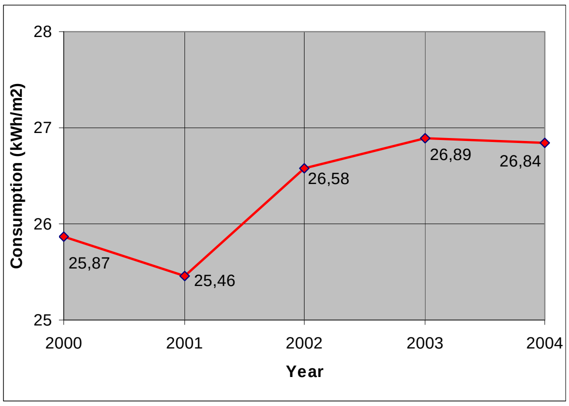

Figure 2 Household consumption per m^2 in Romania - [8, 11]

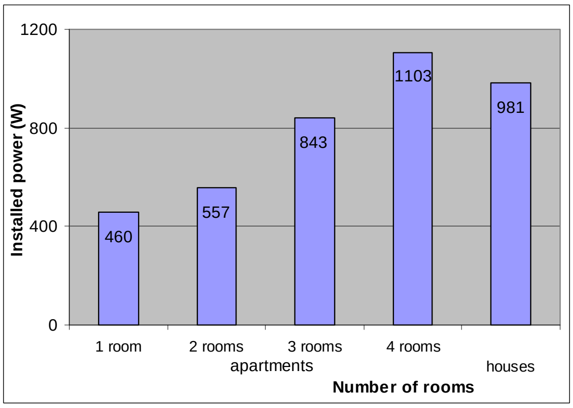

Figure 3 Average installed power in residential lighting - [8]

The analysis of the presented data allows us to estimate a few characteristics of electric energy consumption of households. The annual electric lighting household consumption in Romania in 2004 was about 6.83 kWh/m^2/year (based on the average consumption of 255.3 kWh/ household/year and average household surface of 37.39 m^2/household and the average contribution of the consumption on the lighting circuits - 25% according to the study [2]).

An introductory EnERLIN questionnaire campaign was promoted by two subcontractors of the project in November 2006, to have informative results for a better start of the Promotional Campaign on June - October 2007. This short campaign with 169 answers from the custom people of the electric equipment dealers pointed out that some questions from proposed questionnaires have to be changed, because they are without relevance or confused. An interesting result is related with the average number of the CFLs: 4.06 unit per people. It seems to be too great, mainly due to the fact that the questioned people known well the energy efficient lamps.

The further Promotional campaign will pointed compact areas – all households from a street with single family houses, a residential district of bloc of flats in a city, a county village.

Conclusion

The estimative total electric energy consumption and the total lighting energy consumption in the residential sector, presented as a conclusions of our study, are of 255.3 kWh/household/year, value that fit in the references limits. The mounting of a single CFL in each household of Romania would lead to a decrease of the household electric energy consumption of around 45,246 MWh/year. [8] The predictable economic impact of this study will be established by the adoption of policies towards an electric energy consumption reduction, both locally and nationally. It is essential to increase the awareness of the energy efficiency both by users and by the electric energy providers, in order to reduce the consumption peaks that are specifically due to lighting.

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ARTIFICIAL LIGHTING: HEALTH, ENVIRONMENT AND WELL-BEING

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Nobody can doubt seeing the picture of the figure 1 that corresponds to a city of our days. The intense use of the Artificial Lighting has become a definitive sign of our time. Every night, when the shade begins to invade "the dark face of The Earth", the brightness of our cities manifests the existence of the human being. (Figure 2)

Figure 1

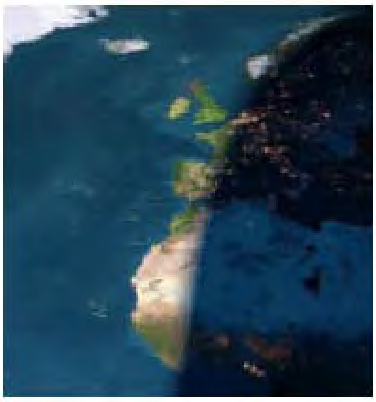


Figure 2

It is a very recent phenomenon to historical scale, unthinkable few decades ago whose complexity and significance hides under the apparent simplicity of "to switch on" and, with this simple expression, to have all the light that we need, doesn't matter the place and doesn't matter the hour of the day. However, it is a phenomenon that, at least for us - lighting professionals - deserves attention; we cannot avoid to think about it

Historical evolution of the Artificial Lighting

The flame, under its three classic forms: torch, oil lamp and candle (Figures 3-6) has been the instrument of the humanity's lighting from the most primitive times of the prehistory.

These Lighting Systems have remained without substantial variations from their beginnings until the XIX century. The cause of it, has possibly to be search in the scarce social demand of lighting; the main and majority activities were developed outside and during day hours: the natural light provided the necessary visual conditions. The combustion lighting, in spite of their weakness and intrinsic defects (mobility of the flame, heat, smoke) was enough for the marginal functions that were assigned.

Figure 3

Figure 4

Figure 5

Figure 6

But the social changes results of the Industrial Revolution gave origin to two phenomenon that invalidated this situation:

- concentration of the activities in areas of easy accessibility to the necessary energy for the production; namely: intensive use of the territory, instead of the previous extensive use.
- prolongation of the periods of activity to accelerate the amortisation of the capital invested: the night, 50% of the available hours, could not be wasted.

Both demands are impossible to satisfy only using solar light, so that the development of the Artificial Lighting Systems took, first time in the History, a strong impulse.

The first intents were aimed at the improvement of the classic systems, in a large part of their fuels: use of paraffin, oil…Appears also the use of gassy fuels: acetylene, hydrogenate, oxhidrica mixtures, distillation gas (called in that time, in fact, “lighting gas”)… A first qualitative springboard goes with the introduction of the “lime light” in the lighting for gas and oil: for first time in the history is no longer the flame the direct luminous source, but an intermediate element took to the condition of “incandescence.”

Figure 7

Figure 8

The same thing happens in the lighting of voltaic arch -spark generated between two electrodes of coal -. In addition that the primary energy was no longer chemical, accumulated in the matter, but electric: potential difference among the ends of a conductor, generated by the flow of electrons along thesame one.

This electric power is the one that investigators as Davy, Goebel, Swan etc. use, and the one that in 1879 allows to T. A. Edison to starting-up the first “electric lamps.” Although the current perspective seems to indicate an easy distance from the “electric globe” to our current Systems, the reality didn't turn out to be so simple. Considering the proximity and transcendence of this period, perhaps it could be convenient to make a “zoom” of attention and detail on the XX century in this accelerated description.

Figure 9

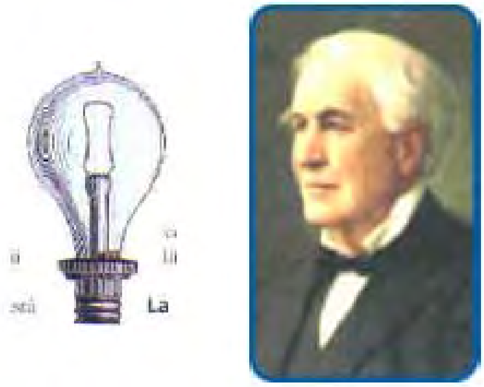


Figure 10

The Artificial Lighting in the century XX

Although at the beginning of the century the lamp of incandescence had twenty years of diffusion, during their first decades the electric lighting had to compete with the combustion systems. The limitations of extension of the feeding nets were one of the reasons that hindered their expansion without a doubt. But another of the causes has to attribute to the limitations characteristic of the electric lighting of those times. Anecdotally, the defenders of gas lighting manifested that "it was necessary to light a match to check if really the filament of a bulb shined." They mentioned with it to the scarce power of the lamps, to the anomalies of electric supply, to the excessive mortality.

Figure 11

Figure 12

Figure 13

In spite of these weaknesses-that, although exaggerated in the anecdote, they were real such an extent that today would amaze us, the electric lighting achieved territory and enlarging its applications in the process that would lead him until its current hegemony.

The inflection point that marks the beginning of the Artificial Lighting just as today we conceives it, takes place before half of the century, near the year 1940. The development of the war industry of North America is conditioned, because the most part the labour population was militarised, by workers from other areas with more demands regarding the conditions of its working environment. It also coincides in this period the growing influence in the industry of psychosociologic Elton Mayo's theories that progressively substitute the precedent taylorist outlines. Everything leads to a substantial increment of the habitual Levels of Lighting – remember the Hawthorne experiences -, and the introduction of Visual Comfort concepts.

Figure 14

From the point of view of the Systems of Lighting, the author of this transformation is the fluorescent tube, with its larger effectiveness, reduction of shine and adaptability of the light tonality. It marks the "star shoot" in a career toward the diversification of luminous sources, increments of effectiveness and power, design of optic systems… until reaching the wide current range of possibilities and, with it, the spread of the Artificial Lighting in types of applications, as well as in their extension and in the qualitative increment of their benefits.

Figure 15

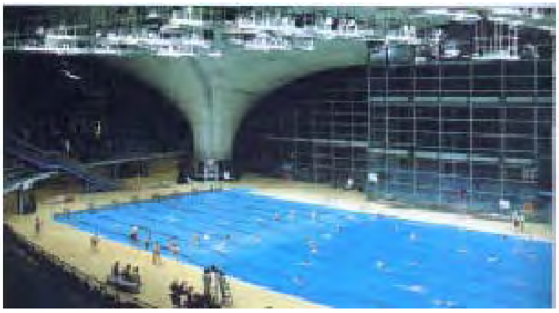


Figure 16

This way, leaving of an initial situation where the lighting demand had to surrender to the limited bid of the existent Systems, we arrive at last decades of the century to have a variety and quality of possibilities that allows to affirm that any desirable light situation is - at least in theory-potentially feasible.

Figure 17

Figure 18

The offer has ended up overcoming on demand, but it doesn't stop in its simple satisfaction: it stimulates it toward higher marks, it extends the requirements of utility and comfort with those of satisfaction, it moves activities (for example: sport) toward the night hours to let enjoy of them, or in other cases to profit the image appreciation that a spectacular lighting can provide them.

Figure 19

From the use of the oil lamp a few minutes of the day, from the shy lighting inside the churches, we have passed to a world where the artificial light switch on when the alarm clock sounds, it floods the labour life, the trip, the social and entertainment relationship, and it only turn off when we retire to the dream.

In the XXI century

It is certain that the trajectory of the Artificial Lighting described previously has provided big benefits to our society. It has enlarged our time, since it allows to prolong the activity at the night hours, it has extended our space, since it allows us the use of interior spaces-even underground -, and it has improved our quality of life, since it allows us to create the good visual conditions for our activity and wellbeing.

The Artificial Lighting is technically a energy transformer system, which processes starting from a primary form - chemistry, thermal, electric - generating electromagnetic radiation. But an important proportion of this radiation is necessary to be emitted in wavelengths inside the visible spectrum, since its purpose is not energetic but informative. The interaction of this radiation with the objects and spaces has to be able to stimulate the receivers of the human retina, activating this way the process of visual perception that, in the great majority of cases, is indispensable so that the observer could carry out his activity.

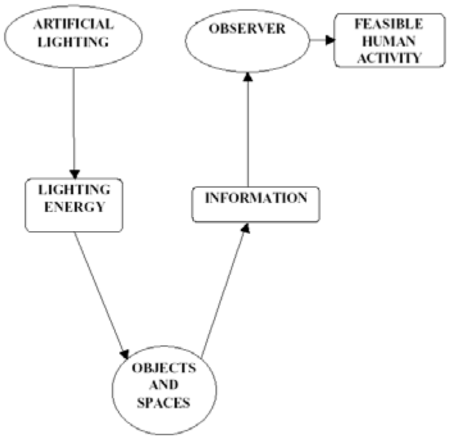


Diagram 1

The great contribution of the XX century has been the quantitative and qualitative improvement of this process, in such a form that, while previously we only were able to generate the necessary visual conditions to do the activities feasible, today we can contribute with the Artificial Lighting to improve its yield, quality, security and satisfaction.

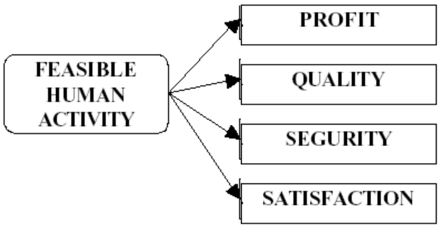


Diagram 2

It explains that our society is immersed in an extensive and intense use of the Artificial Lighting whose panoramic express perfectly the vision of our planet from the space.

Figure 20

(Tangential interlude:

Not confirmed informations assure that the Martian scientific community has taken advantage the period of maximum approach of both planets in August of 2003 to thoroughly study the strangers night emissions of the Blue Planet of electromagnetic radiation in wavelengths in the area between the 300 and 700 nanometers.

It seems that two hypothesis remains divided the scientific community, and they are object of having inflamed discussions in the Congresses, without until the moment none of them has been able to contribute conclusive tests in its side.

The first hypothesis outlines the existence in the atmosphere of the Blue Planet of significant proportions of mercury and sodium steam that would be activated by potent electric storms. Their opponents find inexplicable the temporary and geographical regularity of the phenomenon in addition to the analyses spectrographics of the atmosphere carried out during the day don't confirm such composition.

The second hypothesis is based in the existence in the Blue Planet of some species of primitive beings that would take advantage of the nights to communicate with its gods by light offerings. The opposes to this theory consider that, of existing a similar species, it would necessarily have reached a minimum grade of intelligence, while all the remaining available data confirm the total absence of this quality in the Blue Planet.)

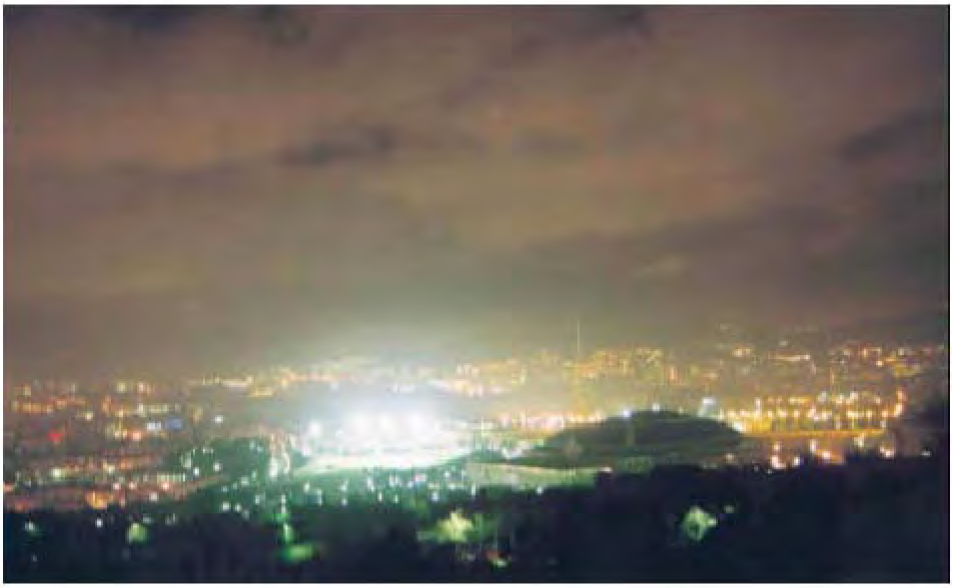


Figure 21

If this vision carries out it with more vicinity that an artificial satellite-and don't say a Martian observatory-we can check that the logical use of the Artificial Lighting, encouraged by the benefits that have been mentioned before, produces, given its intensity, a phenomenon of "overflow." The light doesn't stay in the homes, in the streets, in the places of work… this accumulation of particular uses, invades the general space: the light invades the environment.

And when to final of month we have to pay the electricity invoice, we can deduce that, that same environment that we invade, we extract the necessary resources to have that light.

The outline suggested previously is certain, but incomplete. It forgets that the useful functions of a process always go accompanied by parasitic functions, not wanted but indispensable for the operation of the System. It forgets the necessary resources for the operation, and the residuals generated by the same one.

Consumed resources and generated residues

The previous diagrams express the "lighting intention" and it must to be completed with the "lighting necessity".

Our action is not "costs free" and have "consequences"; in order to realise our function we have to consume material, energy and also informative resources, understanding the last ones not only as technical or scientific knowledge, but also as a "qualitative demands and judgements" , what we call "culture of the light", whose conceptions shape our proposals and they condition answers of the artificial lighting users. Generated residues also takes the three forms: material (lamps, equipment... at the end of their useful cycle of life), energetic (heat, UV and electromagnetic radiation, non optical effects...) and informative (intrusion and light pollution, landscape intrusion...).

I think most of the lighting technicians would agree that our discovery about this "tangential" aspects has been passive: this aspects have been going imposed as the problem got importance and magnitude. Maybe the beginning is in 1970 when the rise in prize of energy, because of war reasons, concerns the sector about energy efficiency; it is only necessary to analyse the Lighting Congress rates before this date and after it, in order to check this inflection point. Even though the discovery has been passive, the answer has generally been "defensive".

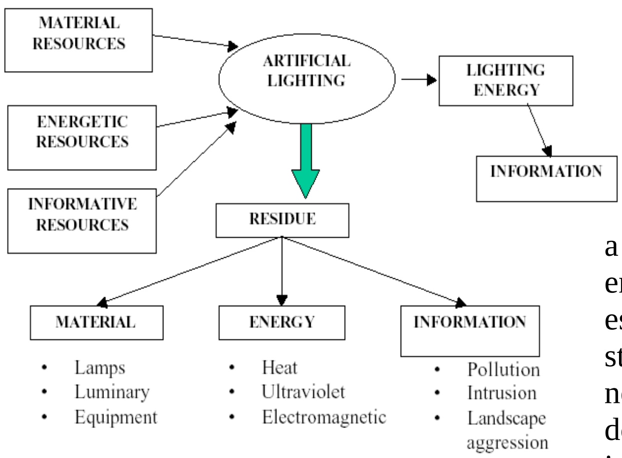


Diagram 3

The brief historical description done before has shown us the XIX Century as time of Artificial Lighting birth in its current conception, and the XX century as time of its development. If the XXI century wanted to be the artificial lighting maturity, it would be necessary to substitute this "passive and defensive" approach, for an active and constructive attitude that allows to anticipate the knowledge of the possible problems and also allows to focus on the outlines that can avoid them or, at least, decrease them. The starting point can be the analysis of critical aspects that nowadays is already possible to know, critical aspects that affect to the environment, the human health and the equality.

Environmental repercussions of Artificial Lighting

As it is already known they point in tree aspects:

- **Energy consumption**

The energy consumption have an effect on environmental problem through:

- ✓ The non-renewable natural resources consumption
- ✓ The emission of pollutants
- ✓ The environment degradation

The whole Artificial Lighting represents a very remarkable percentage from total energy consumption of our society. The estimate changes depending the countries or study methodologies, but all of them were near 2000 Twh at year 1997, and its volume doesn't stop to increase in spite of the great improvements in systems efficiency.

It should be pointed out, also as a general feature, that real energy efficiency of the artificial lighting equipment is far away from its potential value. An example of it is the percentage of incandescence lamps use, which an efficacy about 10-15% with respect to other types, reach a market share between 80 and 90%.

- **Generation of residues**

The specify problem of Artificial Lighting is in two aspects:

- ✓ he environmental noxious materials (mercury, strontium, lead, strange land...) generally included in the electric lamps composition. Moreover, the lamp is the most lasting element of the equipment, its frequent reposition increases the wastes generated.
- ✓ The increasing use in the ballast or other electronic elements with their specific elimination problems.

Figure 22

The treatment of these wastes is difficult and expensive. On the other hand, it must be pointed out a notable effort of the industry in the reduction of these components in the products.

- **Light pollution**

The light emission in direction that are not necessary for its function (sky glow, intrusive light), produce the following effects:

- ✓ It invades natural spaces and modify conditions of alive beings' environment and affecting, therefore, their feeding habits, reproduction, migration, etc… with consequence threats to the ecological balance.
- ✓ It increases the dark sky luminance decreasing the contrast that let appreciate stars, with scientific purposes, amateurs or simple personal view.
- ✓ It invades human habitat being able to cause trouble for the night rest, intimacy, night experience, etc. In some urban areas, children already define yellow as the colour of night sky.

Figure 23

To this effects must add that all this light dispersed in the atmosphere needs to produce it an energy consumption that, instead of a functional using, it causes troubles. It is a really counterproductive consumption instead of an energy waste.

Any of these aspects could be developed with more details and specifying concrete consequences. However, could be more interesting to summarise some considerations of general reach:

- ❖ In spite of the fact that in all the cases we try to introduce measures of correction, the volume of the problems is constantly increasing.

Correction increases linearly, while problematic, crawled by quantitative and qualitative extension of artificial lighting, grows exponentially.

- ❖ Although in the last times informative diffusion related with this problematic has increased, it already exists an ignorance of this problematic.
- ❖ The introduction of corrective measures is slow and difficult.

It could imagine that this difficult is due to:

- Ignorance of the problem
- Underestimate of their repercussions
- Natural resistance to the change

Artificial lighting and human health

Light technicians are used to consider electromagnetic radiation only in its optic aspects, as a transmitter to the brain of information coming from external world.

However, the action of this radiation on the organism is bigger and it includes other access ways apart from optic nerve. Light affects all "human cover", skin and hair, and also inside the eye it generates impulses that, instead of going to the visual cortex, they activate hypotalam and they regulate the development of a lot of physiologic processes in our organism.

In the ancestral evolution of our species this action has only been subjected to the action of solar light, which has a spectral composition and variable intensity, always inside of a limit and specified rhythms. The intensive use of Artificial Lighting in our society is nearly modifying sensitively this conditions, therefore, apart from exceptional affections – like erythema's risk for UV radiation excess - it begin to denote risks of social health that mainly affect phenomenon related with our biological rhythm:

- Depression
- Stress
- Heart rhythm
- Dream rhythm
- Alert grade

denoting in some cases a correlation between work at night –and its corresponding alteration of light cycle- and the incidence of certain types of cancer.

Figure 24

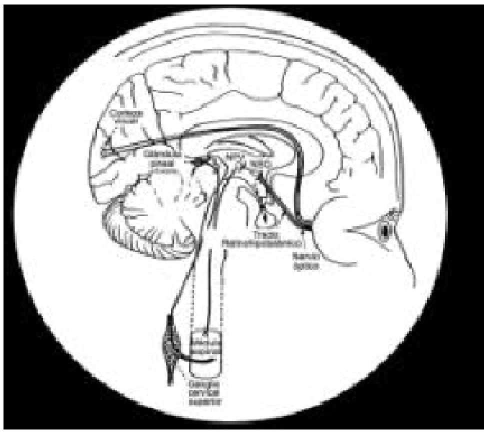


Figure 25

Although the investigation on these topics is very recent and it should even look deeply into a lot of fields, the evidence of relation between health and artificial lighting is already undeniable, and it forces to reformulate positions related with Artificial Lighting using, especially in the labour field.

Figure 26

It also must to be pointed out that this relation does not only behave negative aspects, but also is opening the way to therapeutic application of light and to the development of biologic lighting systems that take advantage of the positive aspects of its incidence on the human being.

Globalisation: Artificial Lighting and equality

Edison was a great technical applications promoter, more than an inventor, among which undoubtedly there is the "electric bulb" , but he was not a good prophet when he affirmed that:
"the electricity will be so cheap that only the rich ones will light with candles".

At the moment, one hundred twenty years passed from the appearance of his lamp, proximally two thousand millions of people – 30% of humanity- does not have electricity and it has to continue using combustion as lighting source. It is not, certainly, part of the humanity economically well being, but it is the most prolific: its birth rate overcomes electrification one, for what this percentage is continually increasing.

Figure 27

Social benefits of Artificial Lighting mentioned are inaccessible for this important volume of human population. They are inside a situation that involve two hundred years behind schedule besides developed society. They use expensive, inefficient, weak and polluting lighting systems, and it is considered that "lighting consumption" (lumen-hour) per inhabitant is near a thousandth compared with other societies consumption.

Nowadays, in globalisation perspectives, it does not seems suitable to bet on the persistence of this situation. But repetition in this field of our habitual outlines could lead an increase maybe unsustainable of the analysed problems, so that it would be recommended to make more imaginative outlines.

Conclusions

Artificial Lighting contribution to the activity and well-being of our society is undeniable, and it is also an achievement that it should not be given up. On the contrary, the effort should continue and extend.

However, it is necessary to recognise that in the way to do it, it has been overcome, without advisement but excessively, certain limits. If, as it has been suggested before, XXI century wants to be qualified as a maturity period, it is necessary elaboration of new positions which clarify initial premises with the consideration more completed of analysed factors, and also opened to incorporate new possible aspects.

Artificial Lighting development has leaned on the technical evolution of systems, but also on social demand that, leaving from a limited objective to satisfy certain services (visual performance), and crossing comfort phase (visual comfort), it has reached some goals of satisfaction (visual amenity). But this evolution has also supposed that, while physiological factors have conserved an importance practically constant on demand composition, the influence of the cultural factors has been developed until being dominant.

Therefore, new phase approach, for which is proposed denomination of sustainability (visual sustained), involves technical measures and procedure one's, but mainly, a true cultural transition. In the current cultural paradigm brightness is success and penumbra is sadness, consumption is status and saving is poverty. In a recent meeting with a politician from our country, and talking about a geographical area so reduced of light pollution, his observation was: "Do you know what that means? That there is not life". To suggest that lighting levels have to be the necessary ones and not to overcome them without reason, that lighting has to stay in its field without invading spaces which do not need it, contradicts the values scale of our current light culture.

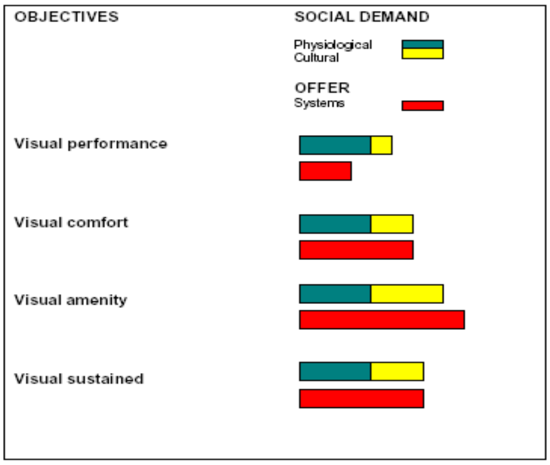
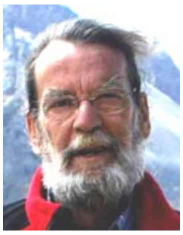


Diagram 4

The sustainable approach suggested does not presuppose to give up the enjoyment of Artificial Lighting benefits, but supplementing with the consideration of its consequences and risks. To join to our legitimated aspirations of auto affirmation the recognition of its limits, an attitude of respect to environment and responsible consumption. To learn again that is light quality - and not quantity - what allows us see, and penumbra can be so gratifying and beautiful as light.

The data exposed in this article indicate that, although perhaps it does not coincide wit their conclusions, light professionals, in the XXI Century, should not continue thinking about our work in the same way. As we were able to suggest new ambitions to our objectives, now we have to be in order to admit new limitations. What benefits can they come from damage the environment and health, or to favour tensions between societies? Let us think it as a new challenge that we are going to know how it can be overcame, just as our recent history shows.

Josep Pla, the Catalan writer, in front of lightened windows in the sky-scrappers of Manhattan, said: " Very beautiful. But who pays for this light ?" It is a good question: who pays for this light?, and what is more important: how does he pay for it?



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Paper presented as Invited Lecture at the International Conference ILUMINAT 2007 Cluj-Napoca, Romania, 31 May - 1 June 2007

PROGRESS ACCOMPLISHED IN THE FRAME OF ENERLIN PROJECT DURING THE FIRST TWO YEARS OPERATION

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In the context of the Kyoto Agreement, the European Community and individual Member States are looking for cost-effective measures to reduce CO_2 emissions and combat climate change. To this end the European Commission carried out the European Climate Change Programme (ECCP) during which it identified, with stakeholders, cost-effective actions that contribute to CO_2 emission reductions. The ECCP identified residential lighting as an important area. To achieve considerable savings in this sector, a coherent strategy is required to transform the lighting market. To ensure a sustainable growth and use of CFL we propose to develop valid promotional arguments and implement coherent promotional campaigns; to train end-users in order to achieve a self-sustained CFL use growth. Concerning energy savings from CFLs, by replacing only one additional GLS lamp by one CFL per household a gain of 11 TWh corresponding to 1.2 Mtn of less CO_2 per annum can be achieved. The consortium work is focussed on the better promotion of Compact Fluorescent Lamps (CFL) for residential use. The main outputs from the project will be the creation of new European CFL-Quality Charter, the design of attractive CFL promotional campaigns, the creation of CFL quality criteria and comprehensive databases.

Introduction

Lighting consumes 19% of all electricity consumption within the world and represents a big energy saving potential still of 20% on all the lighting currently installed in Europe. Old and inefficient lighting technology consumes large amounts of unnecessary energy, creates a cost burden both for local authorities, business and tax payers and produces large and unnecessary amounts of CO_2. The overall project objective is to substantially increase the efficiency of indoor residential lighting in a number of EU Member States, through increased applying of Compact Fluorescent Lamps (CFLs) in this sector.

The overall Energy Efficient Residential Lighting Initiative (EIE-05-0176-EnERLIn) project objective is to substantially increase the efficiency of residential lighting in a number of old end new Member States, through increased penetration of CFL's in the residential sector. This objective should be achieved mainly by

- Introducing a CFL Quality Charter that guarantees for the end-user the CFL quality
- Designing and implementing CFL promotional campaigns adapted to each country sensibility
- Developing web-based training modules for CFL target groups and databases on

CFL market development in Europe and the results of the project

In this paper we will present the progress achieved during the 2 first year of project's operation.

Achieved results

The project web page is fully operational and accessible in: http://www.enerlin.enea.iti a number of documents are yet available in both intranet and public download pages. Due project deliverables till the end of interim period are uploaded and available to any interested person.

The project Advisory Committee is now definitively constituted and active. The role of the AdCom is to give any advice and feedback on the project activities. For this reason AdCom members have full access to project documents like reports (TPR, ITR, FTR) and project intranet. All information is diffused via the project web page and a dedicate e-mail list. All correspondence with AdCom is passing trough the project coordinator.

Data from several countries (not limited to project partners) concerning CFL market (price, volumes, shares…) and residential use (number of lamps per household or/and square meter, number of hour of use…) have been collected, analysed and consolidated. There are some examples:

- In Germany, The power consumption for lighting in the residential sector remains steady at 11.38 TWh (10.2% of electricity usage for lighting). However, the share for lighting decreases, because of increasing power consumption in German households and becomes less than 10%. There exist around 32 lighting points in an average German household, which conforms to a spread of one lighting point in 4 m². The average number of CFL is 6.5 in the private households. 70% of the households have at least one CFL. The three most used lamps burn averagely three hours per day.
- In Portugal, a market report has been elaborated on the basis of a study carried out in the framework of project EURECO, and in documents from the Portuguese Directorate General for Geology and Energy. As example, the study shown that the total residential lighting consumption in your country is equal to 1.33 TWh (12% of the global electricity use). The average number of lighting points is 6.9 but only 1.3 CFLs are present by household and only 50% of houses are equipped with at least 1 CFL. A lamp is burning in average 5.6 h/day (this leads to 2 039 h/annum).
- In Latvia, energy consumption due to lighting in the residential sector is in the range of 23-26kWh/m^2/year for a standard household/flat of 75-100m^2 with around 20-25 ighting points. However, very few data are available concerning the number CFLs per household.
- In Romania, an explanatory study has been realized by UTC-N on January 2006, using feedback reply forms concerning the usage degree of General Service incandescent Lamps - GSL - and Compact Fluorescent Lamps, energy consumption and installed power in households in Western Romania. We

received 295 replies, namely 220 apartments (with 1–4 rooms – living room and bedrooms) and 75 houses (with 2–more than 7 rooms – living room and bedrooms). The installed lighting power has an average value of 0.835 kW/household.

- Following STEM in Sweden, 35% off all electricity is used for lighting, residential sector represent 40% of that amount. Residential sector in Sweden use very inefficient lamps. Retail trade controls the market. Therefore must be persuaded to use Swedish national product specifications while purchasing as well as while marketing the light sources.

Work on the market "barrier" identification is continuing during that project period. There are some new indications in that domain: It should be noticed that beyond classic barriers identified up to now, a new one appeared during the last months: danger due to electromagnetic wave interactions with the human tissues. This has been put in front from some NGOs especially in countries like France (IRENA), however, there is any plausible proof of any danger linked to the power supplies incorporated in the CDF cups. In France, the coordinator in collaboration with the French Illuminating Engineering Association (AFE) and the Syndicat de l'Eclairage issued a formal document that demolishes that unjustified attack. In any case, EnERLIn consortium members and EU should be vigilant in order to face out rapidly similar attacks in other countries. Another point that seems to cause problems for CFLs is that they contain Hg. This is of course true but it should be known that if Hg-free lamps (using essentially Xe) replace existing CFLs the energy quantity necessary, for producing the same quantity of light, would be multiplied by a factor of 2-2.5. On the other hand the coordinator invited SAES Getters an Italian company working on Hg dispensers for lamps to present some invited lectures in key events. Today, as SAES Getters reported in some invited lectures the quantity of mercury inside CFLs is in net decrease (in the order of 2 mg/lamp when EU RoHS allows a maximum of 5mg). It is clear that in this domain more information in destination of the end-user is necessary.

Questionnaires are an easy way to gather information. One important output from EnERLIn project is the creation of a document that includes various questionnaires for end-users and CFL-professionals. Partners develop the questionnaires in various languages for covering various inquires. The questionnaires start to be used by the project partners. There are some actions undertaken as well as some first results:

In Bulgaria, end-users inquiry was executed through random telephone calls. The number of people contacted was about 500, from them 200 replied. The main conclusions are:

- 74%, the population do not have a single CFL;
- The average number of lighting points in a household is 14;
- The average number of CFLs for a household that has such is 2.5 lamps;
- To the question "Do you know anything about CFLs" 60% of the questioned

people responded “Yes” and 40% responded “No”’

- 80% are not satisfied with the CFLs. The main reason for the dissatisfaction of the customers are:
  - ◊ The low-quality CFLs on the Bulgarian market;
  - ◊ The investment is very big;
  - ◊ The energy saved from CFLs can hardly be noticed in the total energy bill.

The second inquiry was addressed to the importers, retailers, architects and designers. Of all the handed out questionnaires 20 were returned filled in. The following results from the inquiry should be underlined:

- The ordinary incandescent lamps have the biggest share on the market. Second come the halogen lamps, and third – CFLs.
- To the question “To what an extent do the existing luminaries for incandescent lamps prevent their change with CFLs?” 21% replied to a large extent, 43% think that this is not of such a great matter and 36% that this is not a big deal.
- In recent years mainly the Chinese manufactured lamps were sold because of their low price. Their bad reputation, however, decreased people’s interest towards CFLs. At present the interest towards quality European lamps is growing.

Comparison of life-cycle-costs, based on: Energy consumption (source: database or individual input); Purchasing price (source: individual input); Typical usage and energy prices. In parallel, a database has been created by e-ster and a first selection of energy-efficient lighting fixtures has been put into it. This database is made based on existing inventories of such luminaries, but mainly on the input from the lighting manufacturers and their trade associations in the EU. Crucial will be the excellent quality of the interior pictures of the lamps, in order to have a tool which can and really will be used by consumers and lighting specifiers to make a (first) selection of (a) luminaire(s). The database is available in www.e-ster.be/enerlin.

In Germany BE-partner developed an Online-tool with a database of energy economy lamps (this includes CFLs, FLs as well as low voltage halogens) that will be continuously amended by all consortium members. This database is similar to this developed for TopTen but it is fundamentally different that because its aim is to include a number of CFLs as large as possible and not only the 10-best examples. The products are ranked by efficiency and it is possible to do direct comparison of 2 - 3 products (Figure 1).

A CEN-STAR Trend Analysis Workshop on CFL Quality has been organised with the initiative of EnERLIn project consortium supported by the Intelligent Energy Executive Agency. The International Energy Agency and the European Commission acted as co-organisers. The workshop has been held on Monday February 26th, 2007 in International Energy Agency in Paris (France). This workshop aimed to explore this issue and begin a process that will enable coordinated international action to reduce reliance on incandescent lighting.

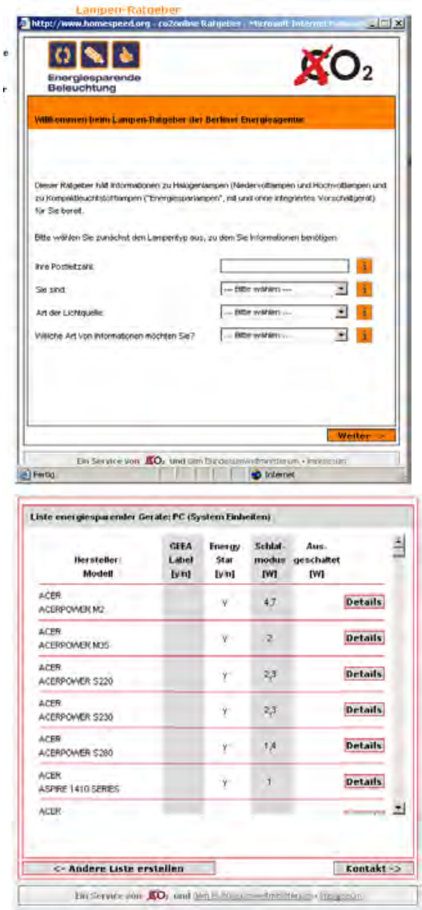

Figure 1 Online-tool (http://www.energiesparende-beleuchtung.de/front_content.php?idcat=6) with a database of energy economy lamps

In focusing the first session on CFL quality issues it aims to address one of the key barriers holding back the adoption of more efficient residential lighting. Identification of strategies to address this and other barriers will be one of the key themes to be considered. More than 80 delegates were present in this workshop. The delegates come from 25 countries. As shown in the following bar chart in figure 2 France, Belgium, UK, Germany and USA represent almost the half of the attendees. As shown in figure 2, 85% of these delegates come from European countries (EU27+Switzerland); 11 delegates come from America, Asia and Australia. We can then consider this event as an international workshop.

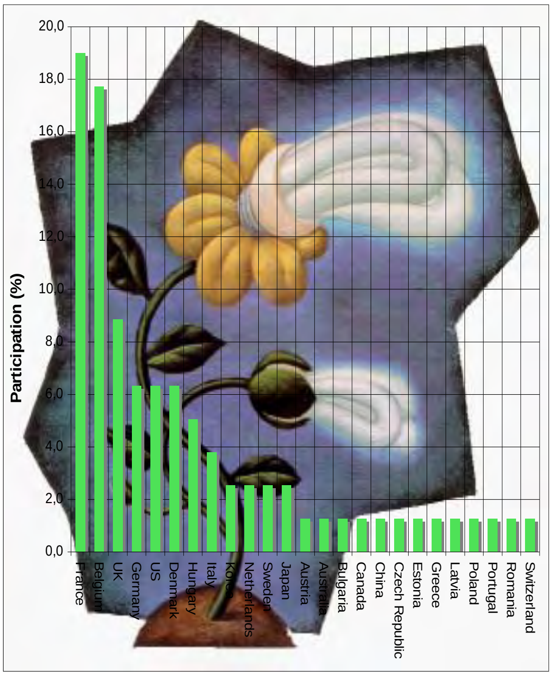

Figure 2 Attendance of CEN-STAR Trend analysis Workshop on CFL Quality

All major lamp manufacturers were present (General Electric Lighting, Osram, Philips, Sylvania Lighting International) as the European Lighting Companies Association represented by his president, the Syndicat de l'Eclairage, the Chinese Association of Lighting Companies sent one representative. European Commission ware present trough representatives from DG TREN and Joint Research Centre (Ispra), as well as the Intelligent Energy Executive Agency. Energy providers like Dansk Energi Net and Berliner

Energieagentur participated, as well as, National Energy Agencies (France, Portugal, Czech Rep., Bulgaria, Italy, Poland, Sweden). The International Energy Agency and the OECD sent also representatives. Representatives from French, Australian, Korean, Japanese, Canadian and Californian Governments were also in the meeting. This list is not exhaustive but illustrates the large interest of the workshop subject.

Most people know that low energy light bulbs exist, but research shows that they are rarely used. Lighting practices in homes are going in the wrong direction as the energy used by lighting increases all the time despite the fact that technology has improved considerably. Energy efficient lighting is now of high quality as well as being attractive and value for money. There is a great need for informational efforts, which lead to action and change. This programme uses exciting and interactive methods to give concrete and measurable results. – a cost effective way for responsible companies to provide greater value to customers and employees and at the same time take an important step for the environment.

Following that event a joint meeting has been organized between EnERLIn Consortium and CFL-Quality Charter team. In this meeting several issues concerning CFL Quality have been discussed: ELC is very favourable to the EU CFL QC in conjunction with Ecoprifile. However ELC believes that the Ecoprofile provides more information. It is preferable if it has a legal base, for example anchored in e.g. EuP directive, and it can still be based on self-declaration. The efficiency shall be adjusted for other parameters. Concerning the switching test: improved switch life (>6000 cycles) requires electronics, which “pre-heat” the electrodes of the discharge tube. This will adversely affect the ignition time: from 0.2 sec to 1-2 seconds. The ELC proposal is to ban only those cold-ignition lamps, with very low switch life (<5000 cycles), and still include all cold-ignition lamps, which typically have 5000-6000 switches. ELC propose to have 3 categories: class A stick types, class B GLS-alike, and class C reflectors.

Based on customers' complains that the CFLs do not give enough lighting a revision in 2-points is proposed for the CFL-QC. This is due both to the start up time 60% light output within less than 1 minute and the "wrong" info about the GLS/CFL equivalence at the package. It was proposed to improve on these factors in the QC concerning. The Danish market experience shows that ignition test is necessary to avoid bad quality: the present test is working (5 min ON/ 10 min OFF, cycles = h life testing for CFL with 10,000 hours life takes 105 days). For colour rendering the Danes as well as many in other Nordic countries would like also to have high quality CR CFLs with five powders at the market as it is available for linear fluorescent lamps.

In fact, human eye is not sensitive to the flux but to the brightness. The brightness is defined as the ratio between the flux and the apparent surface of the lamp. It happen that the old equivalence between CFL and GLS wattages is established for “soft tone” GLS which have equivalent apparent surface, but the consumer try to replace clear GLS with and "equivalent" CFL and in that case the CFL is 150 to 200 times brighter than the equivalent CFL and this gives the impression of lower light quantity. In addition, ENEA's measurements show clearly illuminance special distribution can be completely different between a GLS and a CFL, this reinforce end-user dissatisfaction (Figures 3a & 3b).

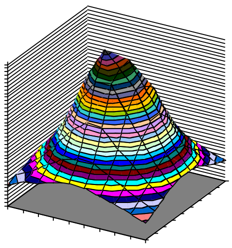

Figure 3a Normalized Illuminance distribution from a 60W soft tone GLS

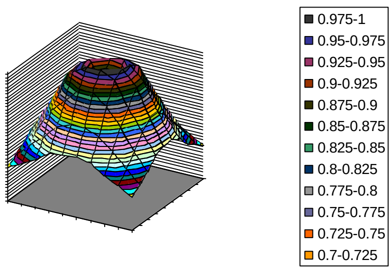

Figure 3b Normalized Illuminance distribution from a 15W CFL

For the version 5 of the CFL-QC, in particular the following suggestions were discussed at the meeting:

- Warm up time (also called run up time). For the CFL stick type within 2 seconds 30% of stabilised light output (earlier proposal was 10%). For the CFL stick type within 60 seconds 80% of stabilised light output (earlier 60%). Philips noted look-a-like GLS use amalgam technology and this obliges to a slower warm-up, if they must be fast they would have lower efficiency, therefore look-alike should have a different criteria.
- Comparison CFL/GLS. In general use an equivalence of 1:4 (e.g. 15W CFL = 60W GLS). It is not a requirement to write the specific wattages, it will be enough to write e.g. "Consumption only 25% of the equivalent GLS lamp". Philips commented that the equivalence is intended to be against a GLS soft white, not to a clear GLS
- Concerning colour rendering several participants suggested the manufactures bring five-phosphors CFL at the market and thus give the customer a high quality alternative for places in the house where you need high colour rendering.

Through the information campaign consumers should be sensitized for taking actions toward energy efficiency via choosing CFLs. The awareness campaign should include as many stakeholders as possible by taking into account budget limitations. Key points of the campaign:

- The campaign should talk to the public generally (main message) and **reach as many people as possible and to specific target groups** (messages tailored to the specific target group via specific information tools such as training materials, design toolkit etc.)
- the messages should be **simple, humorous** and deliver positive encouragement without blaming or offending consumers with a **positive message tone**
- messages should tell target groups that they can make a difference for a common goal – conserve energy with

small investment in CFLs – **call for action**

- a **logo** for the campaign will be created to bring a visual cohesion and credibility on all communication material as well as to create a brand for the campaign
- the messages should be communicated by using as many communication channels as possible

The campaign should include simple messages executed through a mix of print and outdoor advertisements targeted toward different demographic groups throughout Budapest. The primary message of the campaign is to “Reduce your electricity bill through installing quality CFLs in your home.” The campaign should also tell people that there are simple ways to cut their electricity bill as well. Following the above mentioned guidelines we deliver a “Manual for CFL-promotion campaign design” that proposes 12 possible original scenarios for promoting CFLs. These scenarios are adapted to various situations and have different target groups. The efficacy of the scenarios will be tested during the next phase of the project.

The brochure “Right Light in the home” published by the Danish Illuminating Engineering Society has serve as example for EnERLIn. This very illustrated 16-pages brochure is an exhaustive document on efficient lighting in residential sector with advice and practical examples of good application of energy saving lamps at home. It gives useful indications on residential lighting and push people to use more and more CFLs at home under the best conditions. Several EnERLIn partners have translated this document and it is now available in English, Danish, Portuguese and Swedish. For example, in Portugal, as outlined in “Acções ENERLIN 2007” plan, the first action was the publication of the brochure “A Luz Certa em sua casa” with the help of Portuguese Lighting Association (CPI).

Figure 4 The brochure “Right Light at home” (English version). This document is available in the EnERLIn web page

Up to day the consortium organizes 3 major international-level events:

- SEC, in collaboration with the Bulgarian National Committee on Illumination organized a specialized session related to the EnERLIn project within the frame of the Conference “Lighting” 2007 (June 10 to 12, 2007 in Varna, Bulgaria). During the Conference a special poster exhibition was organized.
- UTC-N, in collaboration with CIE (International Illuminating Committee) organized in Cluj-Napoca Iluminat 07 from May 31st to June 1st, 2007. This is a major event in Balkan area and it is supported by CIE. More than 100 people participated.
- KAPE in the frame of the 100-year of lighting industry in Poland organized in Warsaw on June 20th, 2007, in collaboration with national organisms

the International Conference "Energy Efficient Lighting – Perspective of Development in Europe and Poland.

In addition to these major events, the following regional workshops about energy efficient lighting have been also organized.

Lessons learnt

During the past 24 months since the starting of the project, the main lessons learned by the consortium are the following:

- End-user is very regarding on CFL-Quality. Low quality devices "pollute" the market and seriously impede the increase of market penetration of that energy efficient technology. A systematic CFL-quality control is imposed in EU level following a well-defined unique testing protocol and associated with readable and compulsory labelling.
- There is a significant lack of knowledge and data on the penetration and the trends in use of various lighting technologies in households. This is especially true in Eastern European countries, therefore it is difficult to clearly articulate what we would like to achieve with a campaign and whom exactly we could target in order to increase efficient light sources penetration.
- The involvement of many different actors and coordinating with the government authorities and ministries level needs an important investment on time than expected but it is necessary. The politic attention on Climate Change have created activities in many levels in the society which have engaged the EnERLIn people in many discussions to coordinate action.
- Energy efficient lighting has become a more and more relevant topic in all sectors: private consumers, public authorities, and in enterprises. Increasing costs for energy and maintenance, environmental debates, and several EU Directives have especially increased the demand for energy saving solutions in municipalities. Also in the sector of private end-consumers the awareness for environmental integrity and high-energy prices have lead to a rethinking in the use of energy saving lighting. However, the potential for the implementation of environmental friendly and cost saving lighting measurements is still very high. Initiatives such as EnERLIn play a major part in promoting such technologies and help to overcome barriers. The high number of participants in the workshop series and the high demand for advisory on the one hand and the still low number of good practice examples proves this.

Aknwoledgements

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CONTRIBUTIONS REGARDING ARTIFICIAL INTELLIGENCE TECHNIQUES IN INTERIOR LIGHTING SYSTEMS CONTROL

Abstract of PhD Thesis

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Thesis advisor: dr. Florin POP, professor, Technical University of Cluj-Napoca

The Ph.D. thesis was presented in a public debate at the Technical University of Cluj-Napoca, Romania on 30 October 2006. His author obtained the scientific grade of Ph.D. in Civil Engineering.

1. Contents

I. Lighting systems. General notions.
II. Automatic control system of electric lighting according to the availability of natural light.
III. Mathematical model of lighting process.
IV. Fuzzy automatic control system of electric lighting according to the availability of natural light.
V. Neuronal automatic control system of electric lighting according to the availability of natural light.
VI. Fuzzy - neuronal automatic control system of electric lighting according to the availability of natural light.
VII. Conclusions and personal contributions.

2. Thesis outline

The main objectives of the thesis are: the identification and study of the photo parameters determining the quality of the lighting produced by a certain lighting installation, the control – regulation strategies, the control devices and the sensors used in lighting installations, the implementation of a lighting control system with the possibility of implementing the algorithms (which will generate the command for the controlled process) designed using artificial intelligence techniques.

To fulfill the objectives of the thesis, the **Chapter I** approaches studies regarding lighting systems containing general notions with regard to: the quality of lighting, lighting system control – control strategies, control devices and sensors, the actual stage of automatic lighting systems, an illustration by the LUXMATE lighting management system. Consequent to these studies, the author identified the control system type – the Automatic Control System of Electric Lighting (ACSEL) according to the availability of natural light – as well as the significant technological parameter in the accomplishment of the lighting installation control – lighting measured on the work plan.

The **Chapter II** is divided in three sub-chapters; the first sub-chapter contains general notions in the domain of automation. The second sub-chapter contains: the general scheme of an ACSEL according to the availability of natural light and the description of experimental stand. The third sub-chapter presents the conclusions of the chapter.

The current automatic electric lighting control systems use electronic or digital ballasts which control the transformations of the luminous flow of fluorescent lamps. Thus, the author focused on the implementation, as experimental work, of an automatic control system of electric lighting according to the availability of natural light with a technological installation based on two fluorescent lamps.

The experimental stand presented in Figure 1 is composed of: (1) calculation equipment (IBM compatible, PIII, 433 MHz, 64 Mb RAM computer), (2) execution element (accomplished with two modules produced by Tridonic company: DSI-A/D converter, digital ballast PCA 2/36 EXCEL) introduced in the lighting body, (3) the technological installation based on two 36 W fluorescent lamps, (4) light sensor (multifunctional LRI 8133/10 sensor produced by Phillips), (5) data acquisition board with two 8-byte conversion channels (an A/D channel, a D/A channel) produced by the author.

The experimental stand was used in three different situations: to obtain natural lighting values in the work stand under variable meteorological conditions (the electric lighting is null), to acquire data required by the dependence E_{el}=f(U_{cmd}) (E_{el} electric lighting , U_{cmd} control voltage, of the process in the domain [0,10] V), the measurements being taken at nighttime, when natural lighting is null, to acquire data while the experimental stand is functioning in automatic control system.

Figure 1 The exeprimental stand

The section which presents the experimental stand also presents ACSEL behavior according to the availability of natural light under the conditions of implementing a PID position regulator. Due to the lack of a mathematical model of the lighting process, the PID regulator was tuned by using the Ziegler – Nichols experimental method. To tune the PID regulator, it was necessary to bring ACSEL at the stability limit, under the circumstances in which natural lighting (perceived as perturbation signal from the ACSEL perspective) is null. This required performing the tuning procedure at night. After tuning the PID regulator we performed an experimental graph corresponding to the ACSEL reaction to the applying a step input, with the inferior limit with the value 0lx and the superior one 500lx. Following the analysis of this graph we noticed a non-satisfactory behavior of ACSEL from the point of view of the human user’s visual perception. Thus, it was necessary to experimentally study the ACSEL response to a step input for different values of the tuning parameters of the PID regulator. The major disadvantage of using the PID regulator is given by the difficulty of tuning the regulator.

If Chapter II described solutions of implementing an electric lighting automatic control system according to the availability of the natural light, **Chapter III** describes the modality used by the author regarding the determination of the mathematical model that approximate the lighting process controlled by the ACSEL presented in Chapter II. The mathematical model deduced by identification with the method of the smallest squares, recursive or non-recursive variants were used to simulate the behavior of the electric lighting automatic control system according to the availability of the natural light. The regulator was designed by using different techniques from the domain of artificial intelligence. **Chapters IV**, **V** and **VI** deal with the design and implementation of different types of regulators using techniques from artificial intelligence. The different structures of the regulator were implemented under the form of programs in Borland C++ language, version 3.0. The stages that were required for the implementations of different regulator structures on the experimental stand were: at first, regulators were designed and studied. Based on these and on the mathematical model of the process (deduced in Chapter III) we simulated ACSEL. Understanding the structure and behavior of each regulator was followed by the modification of the programs with the purpose of using the same regulator types in the experimental stand. The simulations were necessary in order to avoid the negative influence that a program error might have had on the quality of the process control, including a possible damage of some of the equipment used in the construction of the experimental stand. Consequent to these simulations, the regulators were implemented to the calculation system of the experimental stand and studies were performed regarding ACSEL behavior according to the availability of natural light for different settings of some regulator parameters.

The regulators designed in the present work have two inputs (the control error and the variation of the control error) and one output (the command applied to the process).

There are two types of regulators: of position (the case of the PID regulator – presentd in Chapter II – and the neural regulator implied in ACSEL which do not use the reversed process model – presented in chapter V) and incremental (the fuzzy regulator presented in chapter IV, the first neural regulator presented in chapter V which use the inverse process model and the fuzzy-neural regulator presented in chapter VI which, also, use the inverse process model). Due to the lack of a mathematical model, we performed nighttime measurements of the lighting process output for all the possible values of the command applied to the process input. This data led to obtaining direct and reversed experimental mathematical models of the process.

The Chapters IV, V and VI are divided each in three parts: general theory regarding the used techniques from artificial intelligence, experimental results, conclusions and personal contributions. The configurations of the ACSEL are presented in figures 2, 3 and 4.

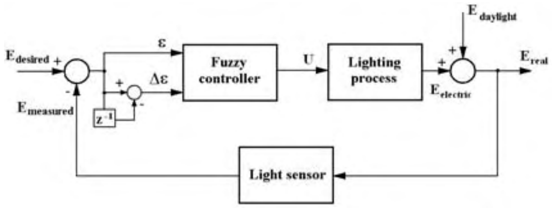

Figure 2 Configurations of ACSEL with fuzzy regulator

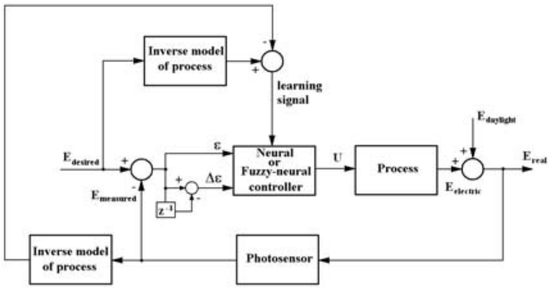

Figure 3 Configurations of ACSEL with inverse model of the process and neural/fuzzy-neural regulator

For all types of regulators, on the basis of the index responses, the ACSEL performances were studied according to the modifications in width of the variation domains of the input/output values in/from the regulator.

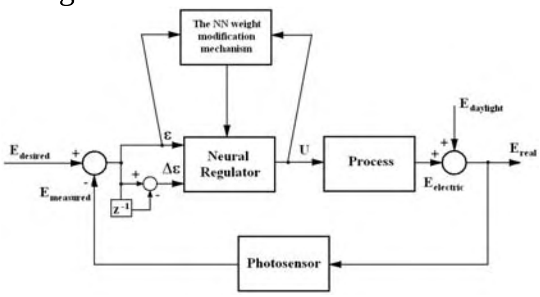

Figure 4 Configurations of ACSEL with neural regulator and without inverse model of process

For the configurations of the ACSEL based on neural regulators, were also performed studies on the influence of the modification of learning rate of the artificial neural network.

The main personal contribution

- mathematical models for lighting process;
- build the experimental stand;
- data acquisition board, for interfacing the computer with: the execution element, the light sensor;
- design of the fuzzy regulator;
- design of the 2 types of neural regulators;
- proposing of a new mechanism of adaptation of neural network weights;
- design of the fuzzy-neural regulator.

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APPRAISAL OF INDOOR LIGHTING SYSTEMS QUALITY

Abstract of PhD Thesis

Ph.D. Student: eng. Mihaela POP, Technical University of Cluj-Napoca
Thesis advisor: dr. Mircea CHNDRIŞ, professor, Technical University of Cluj-Napoca

The Ph.D. thesis was presented in a public debate at the Technical University of Cluj-Napoca, Romania on October 2007. Her author obtained the scientific grade of Ph.D. in Electrical Engineering.

The thesis approaches one of the components of indoor environment – the lighting quality. Lighting is an important instrument in reducing the global consumption of electric power. The "European Greenlight" initiative has been launched in order to stimulate the production of energy-efficient lighting installations. This European initiative generated numerous programmes at local levels. Lighting covers between 5% and 15% of the electric energy consumption in the industrialised countries, while reaching up to 85% in the developing countries. Besides the direct savings resulting from the reduction of energy consumption of lighting installations, indirect energy savings may be achieved from reducing the energy consumption related to heating and air conditioning.

The thesis has been developed in seven chapters:

Chapter 1 **Presentation** describes the main problems faced by the designer and the user of lighting systems when developing a lighting installation integrated in the indoor environment and providing the required visual activity and comfort conditions with a minimal consumption of electric energy, and the manner in which these problems have been analysed and solved in the thesis.

Chapter 2 **Aspects regarding the methods of appraising the quality of indoor lighting installations** develops theoretical considerations selected from literature concerning: (2.1) Sight/Vision and perception; (2.2) Quality parameters; (2.3) Existing systems and methods of appraisal.

An integrated development is provided, in a form accessible to the user, enabling the approach of quality appraisal through its lighting parameters.

Main criteria in assessing the quality of lighting installations are: - *visual performance,* provided by the level of illumination and limitation of glare, - *visual comfort,* provided by the harmonious distribution of brightness and colour rendition, and - *visual ambiance /environment*, provided by the light colour, direction and modelling.

Proper lighting creates a visual environment that enables people to see, to move safely and perform visual tasks with efficiency, accuracy and in safe conditions, without inducing visual fatigue or discomfort. Special attention should be given to both quantitative and qualitative aspects. Even if the illumination level required for the visual task is provided, the visual perception is influenced by the manner of applying the light, by the colour characteristics of the light source and surfaces in the room and the system's glare level. There are other visual parameters, such as the ability of perception and the characteristics of the visual tasks, which determine the observer's quality of visual abilities and influence the level of visual performances.

At the end of the chapter, the global systems for appraising the lighting quality are presented.

Chapter 3 **Software environments for designing and appraising the indoor lighting installations** completes the information available in literature with specific aspects regarding the scheme of optimised designing of lighting installations. In particular, the (3.1) Representation of specific parameters, (3.2) Mathematical model of calculation of indoor lighting systems, (3.3) Designing the indoor lighting systems, (3.4) The European DIALux program, and (3.5) Contribution to the development of a calculation application for sizing the indoor lighting systems are included in this chapter.

The aspects to be developed in the author's theoretical and experimental research, regarding the appraisal of specific lighting parameters, are also highlighted.

The lighting installations should be sized such as to create the most pleasant environment either for work or recreation, at the same time ensuring an energy consumption as reasonable as possible. It is important to not compromise the visual aspects of the lighting installation by the simple reduction of energy consumption. Lighting costs, though substantial, only represents a small fraction of the total costs related to human activity in a certain location. The negative impact of unpleasant visual conditions on the costs related to work quality and productivity is several times higher than the lighting costs. Thus it would be erroneous to save energy on the expense of human efficiency. When designing lighting installations, the standards in force, the features and restrictions of the location and the optimal manner of putting into practice the respective design have to be known.

When designing lighting for a certain application, the *visibility* (visual function) and *visual satisfaction* (environmental function), together with the *installation and operation costs*, *integration in the* building's/location's *architecture*, *installation's maintenance* and *energy efficiency* should be taken into account.

At the end of the chapter, the LSD software application is presented as completed in the thesis with two design modules associated to the calculation and usage of daylight in correlation with electric light. An indoor lighting design scheme using qualitative optimisation, partially developed under the application, is also presented.

Chapter 4 **Possibilities of using the artificial intelligence (AI) techniques in the combined lighting systems** comprises (4.1) AI techniques, (4.2) Adjustment of indoor combined lighting system using fuzzy logic, (4.3) System of automated regulation of electric lighting with process reversed model, (4.4) Conclusion.

Fuzzy sets, fuzzy logic, and artificial neural networks necessary for proposing two applications of automated regulation of the combined lighting system using fuzzy logic and neural regulator respectively, are defined in this chapter.

An application to command the combined lighting system in a room with windows on one side, such as to modify the contribution of electric lighting system is proposed; future research shall be extended to cover the modification of daylight contribution. Fuzzy control of combined lighting uses three sensing elements (one motion detector and two illumination level sensors), a fuzzy regulator as logic circuit of the control system and electronic ballasts with continuous variation (activated by low voltage analogue signal) as execution elements. Data acquired from simulation support the correctness of proposed solution.

An application regarding the use of electrical neural network (RNA) for regulating the electric lighting using in the regulation scheme the reversed model of the lighting process further develops the previous research in this field. The neural network proposed for controlling the lighting process requires a reversed model of the process when the mathematical model is unknown. An experimental model has been used, as a complex of data measured at the input and output of the lighting process, obtaining a group of settings for the neural regulator such as to comply with the imposed/required performance criteria. The neural controller was instructed by the controller's input and output variables.

Chapter 5 **Analysis of an indoor lighting system in real operation conditions** presents (5.1) Light and physiological cycles, (5.2) Lighting and productivity, (5.3) Users' response related to the illumination level and colour temperature of light sources.

In a work environment, activation as well as relaxation moments are needed. The colour and level of illumination may, together, determine such moments. Studies on a work environment (office) where the preferred colour temperature for electric lighting could have been remotely adjusted by tested people, during an entire day, showed that there is no pattern of individual preferences in this respect: everybody has a personal preference (van Bommel, van den Beld, 2004). Researchers unanimously underline the difficulty of comparing visual performances under laboratory conditions, tested on subjects trained to solve the test, with those achieved at employees' workplaces. This real fact may lead to identifying the effect of lighting conditions on the task performance through the influence of lighting and light environment on the human psychology. This is an aspect which the author monitored in an experimental study regarding the users' options in a real work place, where daily activity is performed in continuous operation lighting system. Twelve subjects were included in the experiment. Some net conclusions may be drawn: illumination level of 700 lx and 900 lx are perceived as being "satisfactory" and "good", without a clear separation of one of these; the apparent neutral-warm colour T_{cc} = 4000 K is considered as "good" and "very good"; the apparent cold colour T_{cc} = 6500 K is considered "unsatisfactory" by most of the subjects; most of them consider as "good" and "very good" the association of a 700 lx light level with a warm colour temperature of 4000 K, and an equal number of subjects consider as being "unsatisfactory" of "very good" the association of a high 900 lx light level with a cold colour temperature of 6500 K.

Chapter 6 **Contribution regarding the development of an integrated system of quality evaluation in indoor lighting installations** comprises (6.1) Regulations regarding the quality indicators of lighting installations, (6.2) Proposal regarding a System of appraising the quality of indoor lighting installation, (6.3) Evaluation of weighing factors, (6.4) Analysis of responses to the questionnaires regarding the quality of indoor lighting installation using the method of hierarchical classification, (6.5) Quantification of "lighting system energy efficiency" parameter, (6.6) Quality appraisal toolkit, (6.7) Experimental research, (6.8) Conclusion – critical aspects and further developments.

Electrical energy quality parameters in the power supply network directly influence the proper operation of electric lamps. Discharge lamps (fluorescent, mercury and sodium vapours), halogen lamps and compact fluorescent lamps are sources of harmonic pollution in the network and decrease the power factor. The distortion coefficient may largely exceed the allowed values, the null wire of the three phased network is overloaded, resonance may occur at certain harmonic frequencies. Non-linear charges represented by discharge light sources create problems related to a reduced power factor and the injection of harmonics. Records of wave shapes made in the laboratory and in operating installations are presented.

A significant contribution concerns the proposal of a quality appraisal system of an indoor lighting installation to allow for the evaluation of compliance of the existing installation with the requirements to be fulfilled as regards the photometrical, economical and human aspects.

The inexpensive easy to manage and interpret system consists of two components: one of objective photometry and one of subjective evaluation. The thesis proposes: (a) the determination of daylight factor (calculated or based on photometry measurements), (b) the estimation of energy saving by correlating the electric lighting with the available daylight, and (c) the determination of Quality Level of the lighting installation under appraisal. The proposed method allows for the evaluation of compliance of the existing (or designed) installation with the requirements be fulfilled as regards the photometrical, economical and human aspects.

Evaluation of quality of an indoor lighting system using a Quality Level numeric indicator is *useful*, even if it can only be *partially subjective*. In order to avoid inherent confusion in appraising the quality, it is necessary that this numeric indicator to be adopted specifically at room level, given the particular character of each lighting system, according to the specificity of the respective room. Certain components in the appraisal of quality change their weight depending on concrete requirements of certain activity, thus the user of the proposed appraisal system sets the values of the weighing factors for the appraised lighting system in accordance with the particular data of the room and the importance of the relevant component.

Values of weighing factors of quality parameters revealed by a survey on 52 persons are presented, as resulted from the statistic analysis of the input data. The application of hierarchical classification method on the responses allows for the invalidation of certain input data and the selection of respondents.

Energy efficiency is a relevant parameter in designing high quality lighting. Nevertheless, lighting is designed, firstly, to fulfil the needs of people benefiting from the lighting system, and secondly to be energy efficient.

The energy consumption for lighting depends by the installed power, the swich-on time, and the dimming schemes implemented. "Intelligent" luminaries have their own integral control for occupancy and stepless dimming for daylight control. Depending on the architecture and orientation of the room, the contribution of daylight can result in important energy savings (but could increase the air conditioning load).

The "Lighting System Energy Efficiency" is appraised by analysing the nominal density of power and reference values of this parameter are presented.

The author proposes a toolkit for measurement and appraisal, designed to be simple, comprehensive and flexible. The calculation program used in the toolkit is a component of the LSD application package which calculates the average illumination and uniformity coefficients, presents a chart of illumination distribution, calculates the daylight factor and estimates the energy saving achievable by using the electric lighting correlated with the available daylight.

Chapter 7 **Conclusion and personal contribution** presents the author's main theoretical and experimental achievements, the contribution of the thesis developing the knowledge in this field and the further development of research regarding the quality of indoor lighting systems and the means to ensure it.

The development of the Indoor Lighting Installation Quality Appraisal System, the in-depth analysis of behaviour of a combined lighting system when regulating the lighting with fuzzy regulators or artificial neural networks, processing statistic data acquired from complex questionnaires concerning multiple quality aspects of the indoor lighting installations are only a part of the further development directions of research initiated in this thesis.

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THE 26nd CIE SESSION - Beijing, China 2007

Dorin BEU
Universitatea Tehnică din Cluj-Napoca

The 26nd CIE Session was held in Beijing, China, between 4 and 11 July 2007, preceded and followed by meeting of the Administration Council. All CIE Divisions have their annual meeting during the CIE Session. The Session was opened on July 4th in front of a record audience arround 700 people by Wout van BOMMEL (CIE President). Invited papers were presented by Zhan QINGXUAN (China) with "A Brighter China and a More Colorful Life", János SCHANDA (Hungary) with "100 Years of Solid State Electroluminescence – A Challenge for the CIE" and Ken SAGAWA (Japan) with "Lighting for the Elderly and Visually Impaired". There were workshops on colour rendering, air and surface UV treatment, office lighting and photobiology applications.

From Romania were present Professor Florin POP (vice president of Romanian National Committee on Illumination) and Dr. Dorin BEU (Lighting Engineering Center – UTC-N)

CIE Awards

At the end of CIE Session, the CIE certificates were awarded to: Peter BAXTER AU, J. Derrick KENDRICK AU, Bryan POWELL AU, Dr. Werner K. ADRIAN CA, Prof. Fan SHIFU CH, Zhong XINCAI CH, Prof. Chen ZHONGLIN CH, Antonio CORRÓNS RODRIGUEZ ES, Pentti HAUTALA FI, Dr. Tetsuji TAKEUCHI JP, Hiroshi YOSHIDA JP, Yoshinori YOSHIMURA JP, Dr. Johan van KEMENADE NL, M.Sc. Jerzy PIETRZYKOWSKI PO, Viktor I. SAPRITSKY RU, Raissa J. STOLYAREVSKAYA RU, Ian DAVIES UK

Next CIE Session will take place at Sun City, South Africa in July 2011. The Midterm meeting and the General Assembly will take place in Budapest, Hungary in May 2009.

Distintinguish Services Award

For the first time CIE Board handed out the awards for distinguish services to three experts. These awards will be given at each CIE Session (every four years) to a maximum of three experts for CIE contribution of exceptional value. At the opening of the CIE Session the awards were handed out

- Wyszecki Award for Fundamentals received by Dr. Richard KITTLER;
- Waldram Award for Applications received by Prof. Dr. Kohei NARISADA;
- de Boer Award for Organisation and Administration received by Dr. Yoshi OHNO.

After the CIE Session there is a new Board of Administration, which was elected in 2005.

CIE President	Franz Hengstberger (ZA)
Past-President	Wout van Bommel (NL)
Vice-President Publications	Teresa Goodman (UK)
Vice-President Technical	János Schanda (HU)
Vice-President Standards	Michael Seidl (DE)
Vice-President	Lily Chang Wai Ling (CN)
Vice-President	Ramani Venkataramani (IN)
Vice-President	Gennady Shakhparunyants (RU)
Vice-President	Marc Fontoynont (FR)
Secretary	Ken Sagawa (JP)
Treasurer	Johann Schleritzko (ZA)

Division Directors

Division	**Division Name**	**Division Director**
Division 1	Vision & Colour	Ronnier Luo (UK)
Division 2	Physical Measurement of Light & Radiation	Yoshihiro Ohno (US)
Division 3	Interior Environment and Lighting Design	Jan Ejhed (SE)
Division 4	Lighting and Signalling for Transport	Ad de Visser (NL)
Division 5	Exterior and other Lighting Applications	Nigel Pollard (GB)
Division 6	Photobiology and Photochemistry	Ann Webb (GB)
Division 7	Image Technology	Sabine Süsstrunk (CH)

General Assembly

Chairman: Franz HENGSTBERGER (President of CIE)

AUSTRALIA	Steve Jenkins	AUSTRIA	Peter Dehoff
BELGIUM	Bénédicte Collard	BRAZIL	Iakyra B.C. Bougleux
BULGARIA	Stoyo Platikanov	CANADA	James A. Love
CHINA	Wang Jinsui	CROATIA	Diana Galic
CZECH REPUBLIC	Marek Smid	DANEMARK	Bjarne Nielsen
FINLAND	Tapio Kallasjoki	FRANCE	Dominique Dumortier
GERMANY	Axel Stockmar	GREAT BRITAIN	Nigel Pollard
HONG KONG	Joseph C.M. Leung	HUNGARY	János Schanda
INDIA	Pranab K. Bandyopadhyay	ISRAEL	Inna Nissenbaum
ITALY	Paolo Soardo	JAPAN	Hirohisa Yaguchi
KOREA	Chol Kon Chee	NETHERLANDS	Jan Bloom
NEW ZEALAND	John F. Clare	NORWAY	Birger Hestnes
POLAND	Jan Grzonkowski	ROMANIA	Cornel Bianchi
RUSSIAN FEDERATION	Gennady Shakhparunyants	SERBIA	Miomir Kostic
SLOVENIA	Marko Bizjak	SLOVAKIA	Milan Hrdlik
SOUTH AFRICA	Elsie Coetzee	SPAIN	Fernando Ibañez
SWEDEN	Gunilla Derefeldt	SWITZERLAND	Ivo Huber
TURKEY	Mehmet Küçükdogu	USA	Rolf S. Bergman

Photo 1. Florin POP, Wout van BOMMEL, Franz HENGSTBERGER, Dorin BEU (from right to left)

Photo 2. Mehmet KÜÇÜKDOGU, Sermin ONAYGIL and Florin POP (from right to left)

Source: http://www.cie.co.at/news/news83.pdf

BALKANLIGHT 2008
The 4th Balkan Conference on Lighting

SDR LIGHTING 2008
The 17th Conference of Slovenia Lighting Society

About Balkan Light and SDR Lighting conference

Balkan Light conference has been held every third year since 1999. The conference serves as the premier Balkan and international forum addressing lighting engineering. The conference covers all areas of light, lighting engineering and lighting technology. Previous Balkan Light conferences have been held in following locations:
1999 - Varna, Bulgaria
2002 - Istanbul, Turkey
2005 - Cluj Napoca, Romania

SDR Lighting, the Annual International Conference of Slovenian Lighting Society, has been held every year since 1992. The conference represents Slovenian and

Scope of the conference

The objective of joint Balkan Light 2008 and SDR Lighting 2008 conference is to provide an opportunity to exchange views on key areas of light and lighting engineering, to present progress in technology and to discuss challenges for the future. The subjects cover the main areas of lighting.

The conference will be a meeting place for people from industry, utilities, research institutes and universities who have an interest in lighting research and development.

In scope of the conference also the CIE Division 3 annual meeting and the Division 3 TC meetings will be held.

Authors are invited to submit papers presenting research and technical work related to the theory or practice of lighting. Areas of interest include, but are not limited to:

1. Novelties in lighting
2. Lighting and energy efficiency
3. Health and lighting
4. Lighting quality
5. Standards and legislation in lighting
6. Lighting in architecture

Papers with a student as a primary author will be considered for the Best Student Paper Award, with a cash award of 500 EUR.
Student posters are solicited that present recent and on-going research by students on light and lighting engineering topics.

Program

The technical program includes plenary sessions, invited speakers' sessions and paper sessions. Technical visits are planned at luminaire producers and other industries, utilities and universities. Post session tours and tours for accompanying persons will also be organized.

Schedule

October 6, 2008 - CIE Division 3 TC meetings
October 7, 2008 - CIE Division 3 annual meeting
October 8, 2008 - Conference sessions
October 9, 2008 - Conference sessions
October 10, 2008 - National day
October 10 to 12, 2008 - Post session tours

The meeting place

Ljubljana, the capital of Slovenia, is a lively Central European city lying in a basin at the confluence of the Sava and Ljubljanica rivers, between the Alps and the Adriatic Sea, at 298 meters above sea level. It covers 273 square kilometers and has a population of 276,000. Its climate is basically continental, with January temperatures averaging – 0.3 and July temperatures 20.7 degrees Celsius. Both the residents of Ljubljana and numerous visitors say that Ljubljana is a city made to man's measure. Classified as a medium-sized European city, it offers all the friendliness of a small town and at the same time everything that a capital should offer. Due to its geographical position, Ljubljana is an ideal departure point for discovering the many faces and beauties of Slovenia.
www.ljubljana.si

The conference will take place at M hotel. Hotel is located in western part of Ljubljana, 2,5 km from the city center.
www.m-hotel.si

Important dates

April 1, 2008 - Extended abstract on 1 page

May 1, 2008 - Notification of acceptance and start of early bird registration period

August 1, 2008 - Full manuscript and end of early bird registration period

September 15, 2008 - Student poster submission

Details concerning submission of papers will be given upon receipt of the extended abstract. Conference program and registration form will be issued in April 2008. If you would like to be put on a mailing list, please register on conference web site: www.balkanlight.eu.

Conference fee

The conference fee (330,-EUR) includes attendance at all conference sessions, refreshment breaks, conference lunches, welcome reception on October 7, gala dinner on October 8, farewell dinner on October 9, one copy of the Conference Proceedings and Ljubljana guided tour.

Reduced fees will also be offered for early bird registration and for those who can not attend all conference events.

Student registration fees will be available for

Hotel reservation

It will be possible to make a reservation of a hotel room through the conference web page.

Further information

For further information and contacts use the conference web page ***www.balkanlight.eu*** or the following addresses:

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LIGHTING IN THE NEW WORLD

Cristian ŞUVĂGĂU
BC Hydro, Vancouver

Adaptive Lighting

One word can be used to describe today's workplace: "dynamic." Technology has made the world the workplace. Work is being done via desktop, laptop and cell phone in every conceivable location. As advances in technology and interior design change the way we work, lighting design will play a key role in the office of tomorrow, enhancing communications and positively influencing human behaviour.

Workers' visual needs change with task, age and many other factors. While some employees do paper work that requires higher light levels, others do computer work, where lower lights levels are preferred. Traditional office lighting design provides a one-size-fits-all solution, giving virtually all workers the same amount of light and almost no control. Instead, designers need to provide lighting solutions that are as dynamic as the environment itself.

Thanks to recent technological advances, designers can now give workers control of luminaires and light levels to meet their individual needs. New intelligent control systems provide thus workers with the benefits of a much more personalized lighting experience, and save energy without compromising visual comfort.

These luminaires adapt themselves to each workstations' conditions: dimming according to daylight availability and powering off when the occupants are not present. The networks can be dynamically scheduled according to personal, group and entire work unit specifics. By sensing the presence of the janitorial crews after-hours as they progress through the workspace, the systems power themselves only for the time it takes each workstation to be cleaned saving significant electrical energy.

Benefits of energy-efficient lighting

For most facilities, lighting accounts for over 40% of the electricity bill. Controlling these systems by adapting the lighting conditions to the workplace needs and specific use time can provide a variety of benefits for all stakeholders:

- For building owners and managers, the potential savings from lighting control can be substantial, often reducing energy use by over 30%. When fully dimmable and controllable workstation specific luminaires are used, the overall savings can reach 60-70% compared with conventional static luminaires (see case study).
- Facility management personnel value the increased convenience of maintaining optimal building operations with automated controls.
- For occupants, the advantages of optimal, adjustable light levels can lead to greater comfort and enhanced productivity.
- Intelligent lighting control systems monitor overall energy consumption in a

building and predict when the building is in danger of exceeding preset demand thresholds; automatically reduce light levels in low priority areas of the building.

Personal lighting control products

Personal control does not require new technologies but instead brings common control technologies within workers' reach. Automated or manual, controls make new use of electronic dimming ballasts and network technologies.

Although most people tend to think of manual dimming when they consider personal control, automated controls offer far greater savings potential, providing quicker payback of the whole system. Daylight photocells act like a light thermostat, maintaining set light levels by modulating lights up and down to reduce power consumption as daylight becomes available. Occupancy sensors automatically turn lights off and on when occupants leave and enter the workspace.

Several personal lighting control products are available. Most require the installation of dimming ballasts (if they are not already in place); some suppliers offer an integrated system of lighting, ballasts, and controls. Most of the products also allow designated individuals to control groups of lights (referred to as "*multilevel addressing"*), in addition to giving each individual control over his or her lighting. Following is a short review of the personal control systems available for open and private offices:

Remote-controlled units like PerSONNA (from Lutron) and IRC (Wattstopper) feature a handheld wireless remote control unit and a luminaire-mounted infrared receiver (IR). These systems require fluorescent electronic dimming ballasts and are designed to work with recessed luminaires.

Distributed control systems like Digital microWATT (Lutron), Encelium and CENTURA (Leviton) use dimming electronic ballasts that receive the command signal from end-users (wall dimming units or on-screen icon controls) and interconnected third-party occupancy sensors and/or daylight photocells. The digital controls and the memory of the signals are within local zone panels/ boxes connected to the existing computer network. Proprietary software for control/ power management allows energy mangers to harvest the energy savings and end-users to personalize their lighting spaces. These systems offer inter-operability with HVAC, security and access systems, and can work with any type of office luminaires provided with dimming ballasts.

DALI (Digital Addressable Lighting Interface) is not a system but a digital, non-proprietary communications protocol. Embraced by a growing number of manufacturers (Watt Stopper, Lutron, Lightolier, Osram Sylvania, Philips, Tridonic), DALI is used with digital fluorescent ballasts. Digital ballasts have their individual encoded identification address and provide direct communication to all DALI lighting components, which could originate with different manufacturers. The system can work with any type of office luminaire and can be reconfigured by programming without the need to change wiring or hardware. Transmission of DALI messages can be from DALI-compatible devices like wall controllers, occupancy sensors and daylight sensors, or from a computer device. Manufacturers like Lightolier are already offering DALI-ready products.

Workspace-specific systems like ERGOLIGHT (Ledalite) use special-design direct/ indirect luminaires with dimming ballasts and built-in occupancy sensors and photosensors. The direct lighting illuminates working surfaces, while the indirect lighting illuminates surrounding areas. This enables lights to be placed directly over each work surface, reducing inventory by up to 50% and providing significant savings in operating costs. Luminaires are linked to a local area network, allowing individuals to use their computers to set dimming levels. Energy managers can control all the luminaires for system-wide monitoring or energy savings scheduling. Each luminaire is assigned a unique serial number and is linked to the local area network using a standard network cable. By using dedicated occupancy sensors for each workspace, the system maximizes energy savings by turning lights off when occupants are not at their workstations.

Wireless Controls

Advances in a number of technologies at the beginning of the 21st century are collectively paving the way for the growth of wireless sensor systems. The phenomenal explosion of the personal communications market has dramatically reduced costs and increased the quality of the underlying radio components and technologies. Continued reductions in the costs of computational capabilities also support a distributed architecture for these systems. Embedded intelligence reduces the bandwidth requirements for communications and lowers power requirements, both critical issues for wireless sensors. The technology will also benefit from continuing progress in sophisticated modulation techniques, emerging standards, miniaturization of sensors, and enhanced system reliability and robustness.

Through design improvements, wireless sensor systems of the future will require less power and therefore less maintenance (e.g., battery replacement) than today.s systems. Presently, systems like EcoFlex and EnOcean are self-powering, capturing energy (e.g., thermal, solar, or vibrational energy) from the environment and virtually eliminate power maintenance activities and related costs.

How does it work? A RF signal is generated either through mechanical actuation from a switch or a scheduled transmission from a sensor. These transmissions send packet's of data which contain information:

- change current state (in the case of a switch)
- reading (in the case of a photo sensor).

Keeping thus communication at minimum, these systems are very efficient. The mechanical push of a button and solar power is enough to power transmissions, 30 meters indoors through walls and 300 meters outdoors.

***ZigBee Mesh Networking* -** Mesh lighting wireless control networks use digital addressable ballasts with ZigBee (open protocol for communication) chips. Systems integrate dimming ballasts, occupancy and photo sensors with digital controls. Ballasts providing the DLN (distributed lighting network) backbone become control and communication nodes that can traffic information about the status of the lights.

The systems allow for flexible programming and re-configuration of control zones/ individual units. The ZigBee network is extremely flexible and scalable open to up to 65,000 network nodes. Theoretically, one can use one ZiBee network for an entire university campus.

Recently, researchers at the DOE Lawrence Berkeley laboratories have developed a wireless lighting control prototype that is completely compatible with existing lighting systems and will not require replacement of existing lighting ballasts or existing switches. The system uses an inexpensive power relay and a wireless mote installed in each individual/ group of fixtures, to be controlled via a wireless switch (handheld mobile devices, or wall mounted). Each switch can be programmed to change which fixtures it controls without any hardware changes.

Colour Dynamic – Circadian Adaptation

A new concept of adaptive lighting systems combine personal/ workstation lighting and dynamic ambience based on the knowledge that people are affected by natural light and its changes according to the time of day and the season. Such systems from Zumtobel-Staff (Active Light) and Philips (Dynamic Lighting) use digital dimming ballasts, a combination of fluorescent lamps of warm and cool/daylight colour temperature lamps and a control protocol based on the human circadian light cycle to provide an ever-changing lighting system from dusk to down (cooler colour temperatures for morning and noon and warmer toward the afternoon). The system allows also manual override for private or meeting rooms for mood setting: warmer tone for more confidential activity or cooler for decision making discussions.

Adaptive Lighting - Case Study

During 2005, a team of researchers from the National Research Council of Canada (NRC) conducted a field study on four floors of an office building in Vancouver, British Columbia, Canada, occupied by the province’s electrical utility, BC Hydro. This was a typical deep-plan office building with “cubicle” accommodation and large windows. Intelligent, suspended direct-indirect Ergolight luminaires from Ledalite, located centrally in each workstation provide lighting over most of the floor area. The Ergolight luminaire utilizes three control systems designed to reduce energy use:

- An integrated occupancy sensor (OS), used to detect the presence or absence of people and turn the direct downlight on and off accordingly.
- An integrated light sensor (LS), used to monitor the light levels and dim the direct downlight to harvest the daylight potential.
- Individual dimming control (IC), consisting of a graphical slider on the occupant’s computer screen allowing both on/off switching or dimming of the direct downlight to a preferred level.

The purpose of the study was to collect and analyze information about lighting system energy use and power demand study. Thus, more than 80 lighting workstations were monitored centrally and at the individual level, from January to December, 2005 in three phases:

- Phase 1/ Spring, light sensor was de-activated.
- Phase 2/ Summer, all controls were in operation.
- Phase 3/ Winter, all controls were in operation, and an awareness campaign was conducted by BC Hydro management to boost occupants' control activity.

One half of one floor featured a conventional ceiling-recessed parabolic-louvered lighting system for comparison. The installed lighting power density in office areas served by the Ergolight system was approximately 5.6 W/m2, versus 10 W/m2 in the office area with conventional lighting. The illuminance in the centre of the cubicles at desktop height was similar under both lighting systems, at 400 – 450 lux.

The results indicated that the Ergolight system used considerably less energy compared to the conventional lighting system:

- the installed lighting power of the Ergolight system was more than 40% lower than that of the conventional lighting system,
- in addition, the three control systems combined saved 42 to 47% in lighting energy use compared to the Ergolight fixtures at full power; this translates into overall savings of 67 to 69% compared to the conventional lighting system,
- average daily peak power demand for lighting was reduced by a similar amount,
- used on its own, the occupancy sensor control would have saved between 29% to 38%, on average, compared to the Ergolights used at full power,
- the light sensor control showed a potential for average energy savings in the range of 10 to 20% if used as the only control option,
- average savings were as high as 24% in perimeter workstations, and below 16% in interior workstations,
- potential savings from individual control alone (from occupants' dimming actions) were only about 10%. Frequency of use of individual controls was also relatively low, averaging only 0.01-0.05 control actions per workstation per day.

Overall, the results showed that the provision of Ergolights generated substantial energy savings and peak power reductions compared to a prevailing conventional lighting system. The Ergolights also contributed to a superior indoor environment with benefits on broader, job satisfaction-related outcomes.

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