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Papers

Conferences and symposiums

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The journal **INGINERIA ILUMINATULUI - Lighting Engineering** - is affiliated to the CNRI - Romanian National Committee on Illumination, member of the CIE - Commission Internationale de l’Eclairage. It has a scientific presentation and content, targeted to the continuing education in the lighting field.
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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ENGINEERING EDUCATION AND FORMATION IN THE FIELD OF LIGHT AND LIGHTING

Radu MUNTEANU
Prof. Dr., Rector
Technical University of Cluj-Napoca

Through time, through the competence of its builders, the City of Cluj became more and more important for science and culture, for spiritual freedom and free enterprise, and the most important decisions left in the memory of generations tell us that the contemporary scenery is a creation of the human genius perfected by request, with the appearance of nature, as the spirit of the things in the human spirit.

That is, to see, to feel, to think, to innovate, to build, and, obviously ... to light.

Thinking in this way, our meeting, dedicated to the ILUMINAT 2009 International Conference, is a lesson of scientific honesty, not only a problem of expression but of conception in an effort to convert a present reality for the future through a plan of intuition that mixes the field of light and shadows with the energetic and aesthetic argument.

Currently, the market of lighting systems is extremely dynamic, with a lot of new players, in continue change, and the designers of lighting systems have to adapt to requirements of EU norms and to the competition in this field. UTC-N is implying itself through the formation of lighting specialists and through delivery of know-how to professional companies. By means of different research and design contracts, UTC-N has involved itself in development of studies concerning the rehabilitation of the public lighting system in Cluj-Napoca and Dej, in the design of new representative buildings of the city: the desired building of the Cluj-Napoca Philharmonics, the new stadium.

The engineering education and formation in the fields of light and lighting teaches us not to abandon the efforts by thinking at the destiny, and such a philosophy reveals an important conclusion. The way someone accepts his/her destiny may be more important than the destiny itself, and You have already proven this.

This very important moment is a manifest of our science, speaking a language anyone may understand, because it means to embed, as much as possible, the dream inside reality, and the reality inside the dream. Because the eternal dream of mankind is the light.

The Technical University of Cluj-Napoca is the organizer of this conference, through the Lighting Engineering Center, coordinated by Prof.Dr. Florin Pop, involved for more than 20 years in the field of lighting, editor of a prestigious specialty journal, “Ingineria Iluminatului” and partner or initiator of more European or national research programs. Currently at its fifth edition, this international conference ILUMINAT has started in 2001 and runs every two years, this year being its first jubilee. We use this opportunity to underline the involvement of UTC-N in two recently finalized research programs, a European one: EnERLIn – Energy Efficient Residential Lighting Initiative -, Intelligent Energy-Europe program, and a national one: CREFEN – Information system energy efficiency in residential sector”.

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Thus, the Cluj technical area is a mixture of signs, and a mirror where everybody is looking at its own face, to know oneself better.

We have to have confidence in the times to come, even if more are doubtful about it.

Let us not forget that we pass through the fast-running present, connecting the past to the future, and conferring them a unique and unrepeatable identity.

Certainly, life is always an opportunity to ask ourselves "who are we, where are we coming from and where are we going to?" and Your results answer to all these questions.

Looking insistently towards the world, we understand better than anytime that we live in a permanent change, where the independence of our spirit and the overpass of paradigms lead to innovation, and innovation is more important than the value of tradition. This is, in fact, what You have proved in the last 10 years.

I like to mention that it is an honor to have among us the former eminent President of the International Lighting Committee, Prof.dr. Wout van Bommel, the Presidents of the National Lighting Committees in Romania - Prof.dr. Cornel Bianchi, Germany – Honorary Professor Axel Stockmar, Slovenia - dr. Grega Bizjak, as well as academic personalities in Europe and Romania.

In this sense, we show that the Technical University in Cluj-Napoca ensures the development of cognitive services in the European education area, through a process that has become transnational.

We are concerned by the interna-tionalization of education, the flexibility of academic career through the articulation of the educational system with the other systems, but the future must be designed through the availability of international resources and cooperation.

It is not by accident that at this prestigious conference we have participants from abroad, and the topic is interesting and rich, defining actual fields of scientific research by original papers of clear value.

The Technical University in Cluj-Napoca declares itself a host with the vocation of openness towards the world, underlying, not only for the participants, that we have lines of engineering studies in English, German and French.

We may certainly remember many other things, because memory is like the wind that invents the clouds, or like a rose from the same branch with the reality, but with no thorns.

If the subtle laws of hope push us always towards confession, we will probably understand that we are not going to discover life in libraries, but the books help us understand it, and the scientific research brings progress.

In the framework of the Technical University of Cluj-Napoca we may be capable of scientific dialogue, learning the languages of other nations, which will change the cultural politics of mentalities and will help us become better Europeans.

This homage and scientific event reveals once again that engineering sciences to progress, because they manifest admiration for the success and they know what they owe to the past.

I consider that it is a privilege for me to use this opportunity to congratulate once again Prof.dr. Florin POP on his celebration of 65 years of age and I wish him a long and happy life, together with his family and loved ones.

This make us look towards our colleagues with admiration and respect, but then to turn our looks back towards us with the hope that we will become what we deserve to be!

Finally, I wish this conference success and I assure the participants of my high consideration, showing in the same time that the engineer knows that without dark there can be no light!

Message to the ILUMINAT 2009 Conference.

ROAD LIGHTING IN THE LIGHT OF THE FUTURE

Wout van BOMMEL

Abstract. *Most standards on road lighting have been developed in the eighties of last century. It is time to re-evaluate the validity of these standards especially seen in the context of changed viewpoints of experts, changed environmental circumstances and new technological developments. In preparing new guidelines for road and street lighting all these factors have to be taken into account in the discussion about: why road lighting, quantity and quality of road lighting, where road lighting and when road lighting. This paper gives direction to the discussion and suggestions for research.*

Keywords*: road lighting, standards, new guidelines*

Introduction

Today's European standards for road lighting have been drafted at the end of the nineties of last century. Standards and Guidelines must be adapted regularly to changing insights, changing priorities in society and to changing technologies. The attention for sustainability in view of global heating has led to such a change in priority. For lighting, sustainability has a special meaning when we realize that 20 % of all electricity in the world is used for lighting. New light sources like white metal halides suitable for road lighting and new solid-state light sources offer challenging new possibilities in road lighting. Especially the solid-state light sources (LEDs) give new light distribution possibilities because of their extreme compactness. Adaptable intelligent road lighting is now feasible because the newer light sources are easily dimmable and can be, in a cost effective way, controlled with electronic management systems. Technological developments in automobile lighting have led to intelligent adaptable car light beams (AFS, Advanced Front Lighting System) that put fixed public road lighting in a whole new "light". Traffic density is increased to such a high level that road lighting concepts of the last century are often not relevant anymore. The driving task of today contains different components than those of the past decennia. New discoveries about neurological aspects of lighting are also important for road lighting: first investigations are underway where neurological effects of lighting on car drivers are being studied. Last but not least crime prevention has world wide become an important issue and public lighting of course plays here an essential role.

In preparing new guidelines for road and street lighting all these factors have to be taken into account in the discussion about:

- Why road lighting
- Quality and Quantity of road lighting
- Where road lighting,
- When road lighting.

It is too early to give answers to all these questions. But this paper gives direction to the discussion and recommendations for research needed to come to final answers.

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Why road lighting

The functions of road lighting are, providing:

- road safety
- traffic guidance and traffic flow
- personal security
- identity and prestige to a city, village or area.

In the early years of the last century Waldram [1] defined on the basis of visibility of small objects the "silhouette principle": most objects on roads with road lighting are seen as dark silhouettes against the bright background of the lit road surface. This, in turn, has been the key to the development of the luminance concept of road lighting as still used today [2]. Already early on one realized that the combined effect of road- and car lighting is a negative combination because the vertical component of car lights reduces the silhouette effect. However, in order to limit glare from oncoming cars, car beams could not reach far ahead and thus the negative "combination effect" was limited. With the introduction of Advanced Front lighting Systems (AFS) this now is strongly changed. These intelligent and automatic car lighting systems with specific urban-, highway- and curve beams that reach far and even "around the corner", increase visibility of objects to such an extent that often sufficient visibility can be guaranteed by the advanced car lighting system itself. IR night vision systems that display an image recorded with the aid of invisible IR radiators, on the dashboard (ADAS, Advanced Driver Assistance Systems), will further increase the importance of own car systems as far as visibility is concerned. The role of public road lighting will move much more in the direction of traffic guidance, traffic flow, neurological effects and personal security.

For traffic flow an "old" study of the eighties of Fisher and Hall [3], is today particularly interesting. In a laboratory situation, they studied the time needed to respond to a change in the angle of a "lead car", representing the slowing down of a car driving in front of the test person. Figure 1 shows the results for an initial distance between observer and vehicle of 40 m and for two values of deceleration of the lead car. For low values of road surface luminance, *Lav*, the response time needed, decreases rapidly when the road surface luminance *Lav* increases. This research seems particularly relevant to the current traffic situation. Traffic jams on highways will be less likely to develop when drivers are able to quickly see if vehicles in front of them reduce speed before they really brake and the brake lights go on. Despite the fact that in this study, the road surface luminance is used as the criterion for the quality of road lighting, it seems likely that three-dimensional components of road lighting are key for the effect demonstrated.

With the discovery of a third type of photosensitive cell in the retina of our eye in 2002, [Berson et.al., 4], studies into the neurological impact of road lighting are beginning to get attention as well. Figure 2 shows a car driver whose brain activity is measured during driving. The purpose of this type of research is to examine if road lighting can reduce the number of micro sleeps of night time drivers. If so, the next question to answer of course is which type of road lighting does this most effectively. To illustrate the importance of this type of research: a test where the EEC of drivers was analysed during a night time drive of 415 km motorway without lighting revealed that the cumulative duration of these micro sleeps adds up to more than 6 minutes [5].

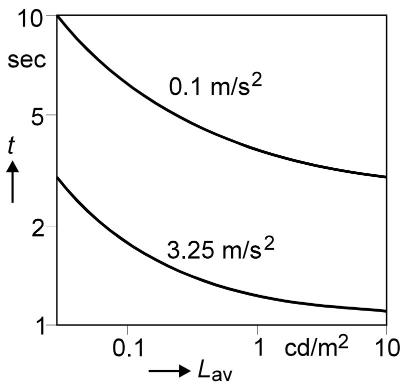

Figure 1 Time (t) required to response to a change in angle of a lead car as function od the average road surface luminance Lav. Fisher and Hall [3].

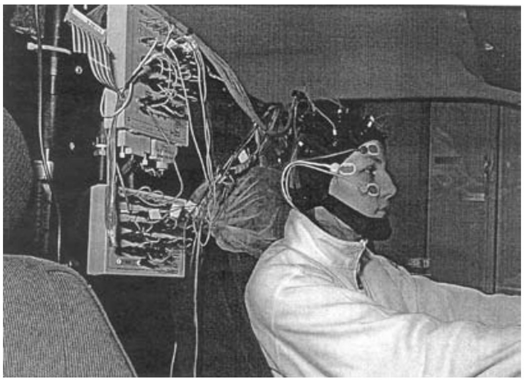

Figure 2 Equipment to measure the brain activity of car drivers while driving (photograph: A. Muzet, Strassbourg).

As stated above the role of road lighting will move more into the direction of personal security. Of course this in particular concerns lighting in areas where pedestrians are on the streets. Unfortunately this aspect becomes also more and more important for people who move in their cars from A to B. Not for nothing, nearly all modern cars have an automatic option to lock the car from the inside. Especially many women choose for their journeys in the dark those roads that have lighting, even if this means a longer detour.

Quality and quantity of road lighting

At times when traffic density is relatively low and speeds are high, the visibility of objects and lineation is more and more taken over by the own advanced car lights as already discussed above. The traditional concept of road surface luminance lighting seems under these circumstances less relevant. It is not yet known whether neurological research, also discussed above, can indicate what kind of road lighting parameters can perhaps reduce micro sleeps.

In built-up areas but also on rural roads, personal security becomes the more determining factor in road lighting. Already in the eighties Caminada and van Bommel [6] have demonstrated that for one of the most important aspects of personal security, the recognition of faces, the three-dimensional component of lighting is essential. We came to the conclusion that the "semi-cylindrical" illuminance at face height is a good indicator for this component. Meanwhile, other measures such as the vertical illuminance on face height, semi-spherical illuminance at ground level are proposed as well.

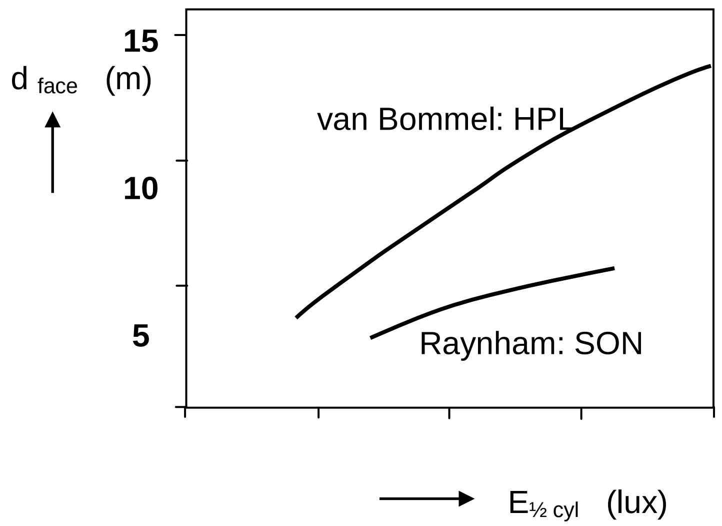

Figure 3 Identification distance d, under residential area lighting circumstances in dependence of semi-cylindrical illuminance E½cyl, with white high pressure mercury light HPL and with yellowish high pressure sodium light. Raynham [8].

Since the introduction of the low pressure sodium lamp in 1932, many roads and streets in the world are lit with yellowish, low or high pressure sodium lamps. The contribution of colour to face recognition is neglectable with these lamps with a low colour-rendering index between 0 and 25. White metal halide light sources with a long lifetime and high efficiency and colour rendering around 80, are only just a few years available for road lighting. White LED light sources with high efficiency will rapidly become available. An investigation of Raynham compares results of his own research with that of Caminada and van Bommel. That investigation shows that white light with a colour-rendering index of at least 40 substantially contributes to face recognition and therefore allows for lower lighting levels [8]. Figure 3 quantifies the differences in terms of required semi-cylindrical illuminance.

A British directive for road lighting in residential areas permits for this reason lower light levels if that lighting uses white light. An additional advantage is that peripheral or off-line vision improves with the use of white light that has a higher blue component than yellowish light. This is because of the larger sensitivity for blue (and green) light of the mainly peripheral located rods in the retina of our eyes [9]. This offers both for pedestrians in built-up areas and for car drivers on rural roads an extra safety advantage. “Natural” white light finally also gets a more positive subjective assessment of residents than yellowish sodium lighting [10].

Given the importance of the quantity of light in the context of sustainability, the concept of “visual ergonomics” as introduced in the seventies by Vos and Padmos is today very relevant [7]. Visual ergonomics in its simplest form means that one should look for alternatives to enhance the visibility of visual tasks other than by "more light" only. There are for example traffic situations that are so complicated and confusing that a lot of light is needed to enable the driving task. Of course, a better alternative than "more light" is to simplify the complexity the driver has to deal with. Dynamic road markings (e.g. LEDs built into the road surface) to visually simplify complex situations without (extra) road lighting, is another example of applying the visual ergonomics concept.

Where lighting

It is not the lighting expert who should determine in which areas road lighting should be present. That is a decision where politicians should play a decisive role on the basis of arguments such as cost-benefits, importance of crime prevention, importance of promotion and importance of giving identity to an area. If chosen for lighting the lighting designer is responsible where the light in the space should be. We discussed already about luminance of the road surface and thus horizontal illuminance, semi-cylindrical illuminance on face height or half-spherical illumination at ground level. It seems important that the lighting has a three-dimensional component. Here, a statement of the Dutch lighting expert Joh. Jansen in 1956 published in International Lighting Review is especially today relevant [11]:

"A city street with dense motorized and pedestrian traffic is not much else than an elongated room. Just as in a factory hall, that street will have to receive light as to enable people to see quickly and distinctly what is happening. This no longer has anything to do with the classic luminance contrast between vehicle and bright road surface"

The fact that the three dimensional component is important also means that extra attention is needed to avoid light in directions where it can disturbing. The direction of view of a car driver is usually downwards but a pedestrian also looks above the horizon in order to orientate himself. It is therefore not surprising that different glare systems exist for car drivers (TI) and for pedestrians ($I.A^{0,5}$). With the introduction of new compact light sources for road lighting including LEDs, it is important to note that during the development of both glare concepts, compact light sources for road lighting did not yet exist. Improved glare restriction concepts for both car drivers and pedestrians, preferably based on a same basic concept, are needed now.

Light that directly or indirectly brightens the sky and/or buildings can rightly be called light pollution. International guidelines for limiting light pollution do exist and should be followed. Restriction of light pollution may automatically improve the overall efficiency of a lighting installation because light spillage outside the area to be lit is avoided. The restriction of obtrusive light or light pollution in fact is very much a sustainability issue.

When lighting

The circumstances that determine whether or not lighting is needed change continuously during the dark hours. Road lighting should therefore automatically adapt itself to those circumstances. Measuring devices for circumstances like weather, traffic density, composition of traffic, traffic flow are readily available today and can be easily applied. Intelligent lighting driven by these sensors can significantly contribute to costs and energy savings. LEDs that simple can be regulated between 0 and 100% light output will accelerate putting these intelligent systems into use. In draft CIE Publication Nr. 115 (2nd edition) socalled weighting factors are defined that indicate under which circumstances road lighting levels can be reduced with one or more classes. Table 1 shows the main table from that draft publication.

Table 1 Parameters and weighing factors for the selection of lighting classes for lighting in residential areas (draft CIE Publication 115 [CIE, 12].

Parameter	Options	Weighting Factor
Speed	Low	1
	Very low (walking speed)	0
Traffic volume	Very high	1
	High	0.5
	Moderate	0
	Low	-0.5
	Very low	-1
Traffic composition	Pedestrians, cyclists and motorized traffic	1
	Pedestrians and motorized traffic	0.5
	Pedestrians and cyclists only	0.5
	Pedestrians only	0
	Cyclists only	0
Parked vehicles	Present	0.5
	Not present	0
Ambient luminance	Very high	1
	High	0.5
	Moderate	0
	Low	-0.5
	Very low	-1

On the basis of data of the total road lighting park in all European cities we come to the conclusion that general application of this system in all European cities would save some 14 TWh/year. This is the equivalent of 7 medium electricity power stations (each of 2 TWhr/year). If in this table also the earlier-mentioned advantage of white light would be built in as a weighing factor, the saving still further increases.

Conclusion

Given the increasing use of advanced automotive lighting and driver assistance systems in the coming years we will see a shift in the role of road lighting from visibility of objects to traffic guidance, traffic flow and personal security. The three-dimensional component of road lighting will therefore become more important. Concepts for this have been proposed but should internationally be standardized. Neurological investigations into the possible impact of road lighting to reduce nighttime micro sleeps of drivers have just been started but could also play a role in the definition of road lighting quality parameters. Application of the concept of visual ergonomics can lead to important savings in lighting, energy, light pollution and costs. General application of intelligent, adaptive automatic road lighting installations provides major savings. New, compact light sources including LEDs will play an essential role in all of this. New measures for glare restriction are required when applying these modern compact light sources. Restriction of light pollution is important to limit annoyance and to keep the skies dark for astronomers but probably even more important: it is a sustainability issue.

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Wout van Bommel, has more than 40 years experience in lighting application, ranging from outdoor and indoor lighting to non-visual biological effects of lighting. On joining Philips Lighting in 1972, he was involved in fundamental lighting application research. For the period 2003 – 2007 he was president of CIE (Commission Internationale de l'Eclairage) and he is for the period 2008 – 2011 Board member of IDA (International Dark sky Association). In 2004 he was appointed consultant professor at the Fudan University in Shanghai.

Prof. van Bommel has published more than 100 papers in national and international lighting journals in different languages. He is the author of the book "Road Lighting" (translated in the Chinese and Polish language), a "standard" in its field. All over the world he has presented papers and given invited lectures at different Conferences. He is often invited as lecturer for lighting courses of universities, schools and for other interest groups at many different places in the world.

After his retirement from Philips Lighting March 1st 2009, he started his own lighting consultancy: "Wout van Bommel Lighting Consultant". He advices as an independent Lighting Consultant, lighting designers, researchers, companies municipalities and governmental bodies.

Invited paper presented at the 5th International Conference ILUMINAT 2009, 20 February 2009, Cluj-Napoca, Romania.

HYBRID LIGHTING SYSTEMS

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Abstract. *This paper reviews developments in hybrid light guidance systems. In these daylight and electric light are simultaneously delivered into a building where they are combined and distributed via luminaires. The technology used in hybrid systems, both conceptual and realised, is discussed. The paper speculates as to their likely performance in terms of daylight delivery; capital and running costs; user reaction to the systems; potential impact of the systems on the building which they light; and suitable design methods.*

Keywords: *light guidance, hibrid systems, costs, human response*

1 Introduction

In vernacular architecture elements evolved to reflect, re-direct or control daylight. Conventional glazed windows can provide daylight some five metres into a building. But since daylight levels decrease asymptotically with distance from the window, a disproportionate amount of daylight and associated heat gain must be introduced into the front of a room to provide small amounts of daylight at the rear. Attempts to direct daylight to areas remote from the building envelope using techniques such as atriums and skylights are limited in effectiveness by contemporary technology. Over the last twenty years or so, a number of highly efficient reflective and refractive materials have been developed making possible what has become known as 'light guidance'. Light from both daylight and electric sources may be guided. The main type of guided daylight is known as Tubular Daylight Guidance Systems (TDGS). This introduces daylight deep into electrically lit buildings, although current practice is to use the electric and daylight systems separately with minimal interaction (see Table 1).

Attempts to better combine the delivery of daylight and electric light to the same space use two main approaches - 'integrated lighting' and 'hybrid lighting'. Their main characteristics are summarised in Table 1. This paper reviews developments leading towards the hybrid concept and describes a number of systems, realised or otherwise. It speculates about likely issues of system performance, costs, user response, building relationship and design methods.

2 System descriptions

Unless otherwise stated the performance and other data quoted in this section is from the sources cited.

2.1 Daylight guidance

Although TDGS is the only form of guidance having wide commercial application, a number of other types, notable because their technology has been adapted for use in integrated and hybrid systems, are also reviewed in this section.

Table1 Approaches to delivery of daylight and electric light

	Tubular daylight guidance	**Integrated lighting**	**Hybrid lighting**
Daylight sources	Skylight and sunlight	Skylight and sunlight	Sunlight
Daylight delivery	Tubular daylight guidance	Conventional glazing, beam daylighting or tubular daylight guidance	Tubular daylight guidance
Electric lighting	Conventional luminaires at point of use	Electric light may be guided as supplement to daylight.	Electric light may be guided.
Method of use	Separate daylight and electric lighting	Uses daylight as main source automatically supplemented by electric light as required.	
Control system	Usually no daylight linking	Fully daylight linked	
Output device	Separate daylight output devices and electric luminaires	Separate output devices for daylight and electric light. Electric lighting may be ‘intelligent’.	One output device is used for both lighting sources.
Quality of delivered light	Optical control of daylight by diffuser and electric light by luminaire. Source colour differences apparent	Optical control of daylight depends on particular system. Electric light control by luminaire. Source colour differences apparent	Optical control of all light by luminaire. Single source colour.

2.1.1 TGDS

TDGS are cheap, simple passive devices effective under both clear and overcast skies. Their main application is in single storey buildings. Light transport is usually via a rigid tubular guide lined with a highly reflective material. A clear polycarbonate domed collector at the upper end may be horizontal or inclined at some angle to the guide axis. A diffuser at the lower end distributes light within the building. CIE Report 173 discusses system characteristics and selection and sets out standard photometry and design/analysis methods [1]. Using these it is possible to estimate likely flux outputs, system efficiencies and daylight distributions of TDGS under a variety of sky conditions. The CIE Report puts forward the Daylight Penetration Factor (DPF) to quantify daylight penetration via light guidance devices. This is analogous to the Daylight Factor (DF) used for conventional glazing. Whilst DF is the illuminance received at a point indoors expressed as a percentage of the exterior skylight illuminance, the DPF is the illuminance received at a point indoors via a light guide expressed as a percentage of the global exterior illuminance. Area weighted average values of each may be calculated (ADPF or ADF respectively). Combination of the two quantities (ADPF+ADF) enables a quantitative assessment of the total daylight contribution from the various daylight providers.

Post-occupancy evaluation studies of TDGS in offices suggest that although TDGS devices are recognised as daylight providers, current design practice produces ADPF+ADF of the order of 1% on the working plane. This was not considered by users to produce a well day-lit interior, a result that led to the suggestion that a design criterion nearer 2% may be required [2]. A long term cost study showed that TDGS provided poor economic return when viewed solely in cost terms but that this needs to be balanced by consideration of the value of the daylight delivered into a working area [3].

2.1.2 Façade mounted systems

These consist of a façade mounted light gathering device oriented toward the equator, a horizontal guide system within a suspended ceiling, and output devices located deep in a building. They are used in conjunction with conventional lower windows and electric lighting systems. The light collector is a curved mirror or other device which deflects daylight into a mirrored guide. This technology is intended for office buildings but only a few systems appear to have advanced beyond the prototype stage. Courret et al. report the design, simulation and full scale testing of an 'anidolic ceiling' - a rectangular cross section horizontal duct using anidolic optics at each end to collect and distribute light from a predominantly overcast sky [4]. Validation of the device by both simulation and measurement under overcast skies established that DF on the working plane was enhanced at the rear of a room, some 4% at depths of between 3 m and 6 m into the room, or approximately 1.7 times the un-enhanced value. A value of 32% efficiency for the whole system is quoted.

Façade mounted systems have been used in tropical latitudes. A proposal for an office in Kuala Lumpur uses fixed laser cut panels to deflect high angle sunlight axially into a polished aluminium duct and extractor laser cut panels inside the duct to redirect light into the room. Studies indicated that daylight levels of between 200 and 300 lux would be achieved on the working plane some 6m from the façade during working hours [5].

2.1.3 Active guidance systems

The Himawari system, developed in Japan, collects and concentrates sunlight using tracking fresnel lenses. Light may be transported up to 200 m by optical fibres, and distributed using a range of custom made luminaire-like devices. For example a 15 m long cable each of six fibres would deliver 1630 lumens from 98000 lux of direct sunlight on the collector [6]. A major advantage of fibre optic transport is illustrated by the fact that some Himawari systems have been retrofitted to existing buildings. They have a large capital cost which is unlikely to be justified for other than specialist applications.

2.2 Integrated lighting systems (ILS)

'Integrated lighting' is a generic name for systems which deliver daylight and electric light separately but which are equipped with control that maximises use of available daylight. There are two main approaches.

2.2.1 Integrated Skylight Luminaire (ISL)

The ISL combines in one unit a skylight with a sunlight control device, an electric lighting system, and a photosensor control system to automatically dim the electric output. It delivers daylight via 1.2 m x 1.2 m double-glazed clear roof-lights that capture both sunlight and skylight [7]. This is supplemented by twelve T8 fluorescent lamps. The two light sources are linked by photosensor and luminaire controllers which automatically reduce the electric light outputs when sufficient daylight is available. A 1.2 m-high daylight diffuser box is mounted below the roof-lights and distributes the sunlight via white acrylic diffusing panels.

2.2.2 Intelligent lighting systems

In essence these are an electric lighting system with enhanced controls which seek the maximum benefit from any source of daylight – guided or otherwise. A number of manufacturers market systems of this nature, some of which are based on 'open' communication protocols such as digital addressable lighting interface (DALI). All are integrated into an appropriate building management system. Luminaires are equipped with, variously, integrated network controls, occupancy sensors, personal dimming or daylight dimming. Depending on the individual circumstances of use, the combination of features listed above can yield substantial energy savings. For example a field study of a deep plan office building having luminaires with occupancy sensors, daylight linking and individual dimming control saved 69% compared to a conventional lighting system. Electric lighting substitution by daylight accounted for 20% of this total [8].

2.3 Hybrid lighting systems (HLS)

In the systems described so far light is delivered using separate output components whose optical properties may differ substantially. In 'hybrid lighting' daylight is combined with electric light prior to delivery. Optical control is more akin to that of an electric luminaire and the two sources may not appear as distinct. Table 2 summarises some features of HLS. It also includes the authors' estimates of system efficiencies for one and two storey applications. These are based on cited information on size and efficiency of individual components. Approximate flux outputs for output devices are based on the estimated one storey system efficiency and cited values of external illuminance.

2.3.1 Enhanced tubular daylight guidance

The first developments in HLS lighting were enhancements to TDGS. These use heliostats and combine electric and natural light within the guide rather than at point of use. The Arthelio study developed systems combining daylight and electric light from sulphur lamps, and culminated in the construction of two large installations – one of which was in a single storey warehouse in Milan [9] [15]. This uses a single axis light capture head based on a Fresnel lens. The sunlight is then reflected via an anidolic mirror into a 13 m-long, 90 cm diameter circular guide lined with prismatic material. A diffuser unit located at the end of the guide delivers daylight illuminance varying between 100 and 400 lux to the working plane. This is supplemented from two two horizontal prismatic guides powered by dimmable sulphur lamps which top up or replaces the daylight as necessary.

2.3.2 Hybrid Solar Lighting (HSL)

This was developed by Oak Ridge National Laboratory for public buildings in areas of the USA where direct solar radiation is greater than 4 kWh/m^2/day and cooling is a major design concern [10]. The sunlight collector is a primary 1.22 m-diameter parabolic acrylic sun-tracking mirror with an elliptical secondary mirror. The latter separates the visible and infrared portions of sunlight and focuses the visible sunlight into a bundle of 127No 3 mm diameter optical fibres used for transport. The optical fibre system delivers the sunlight to the end of a side emitting acrylic rod located inside a conventional 1.2 m x 0.6 m electric luminaire also equipped with dimmable fluorescent lamps. A control system tracks the sun; light sensors monitor daylight levels; and electronic dimming ballasts regulate the electric light output to a pre-determined level. System losses are of the order of 50% for single-story application with an additional 15-20% for a second storey [11]. One collector can power 8 to 12 fluorescent, or 30 to 40 reflector luminaires, so lighting an area of about 100 m^2, and displaces about 1 kW of electrical lighting load. On a sunny day one HSL system is reported to deliver 50 klm per group of luminaires.

Table 2 Hybrid system summary

Name	**Light collection method**	**Light transport method**	**Daylight output device**	**Electric sources and location**	**Daylight system efficiency at (i) 4 m (ii) 8 m** *(see Note 1)*	**Approx. device output (*External illuminance*)** *(see Note 1)*
Arthelio	Heliostat	Hollow light guide	Side emitting prismatic guide	Sulphur lamp in horizontal light guide	8% for 20 m guide: under overcast sky 50% under direct sun	a) not measured b) 25000 lm *(15000 lux)*
HSL	Parabolic mirror heliostat	Optical Fibres	a) Side emitting acrylic rod b) End emitting rod	a) T5 tubes in luminaire b) incandescent in luminaire	(i) 50% (ii) 30%	6250 – 4170 lm *(100000 lux)*
UFO	Fresnel lens heliostat	Liquid light guide & Optical Fibre	Luminaire with acrylic diffuser	HID remote & T5 in luminaire	(i) not measured (ii) 3.4%	3000 lm *(100000 lux)*
SCIS	Multiple mirrors & lenses system	Prismatic Guidance	Prismatic guide with diffusing extractor	T5 Fluorescent tubes in guide	(i) 25% (ii) 25%	25000 lm *(Not stated)*
Parans	Mini Fresnel lenses Heliostat	Optical Fibres	Diffusing luminaire with end emitting optical fibres	T5 or compact fluorescent lamps in luminaire	(i) 40% (ii) 30%	7500 - 10000 lm *(75000 lux)*

2.3.3 Universal Fibre Optics (UFO)

Sunlight is collected by a roof mounted heliostat with a 1m-diameter Fresnel lens and delivered to luminaires via 10 m-long 20mm-diameter liquid light guides [12]. In addition light from two 150 W metal halide lamps, located adjacent to the heliostat, is delivered to the luminaire via plastic fibre optic cables. The luminaires contain a coupling system linking both liquid and optical fibre guides to the edge of a 20mm thick 'Prismex' panel and delivers an even brightness across its emitting surface. The luminaire also has two T5 fluorescent lamps located along the edge of the emitter. The system is photocell controlled such that when daylight fails the luminaire switches to light from the metal halide lamps. A prototype, installed in Athens, had a flux output of 3060 lm for a normal illuminance on the collector of 90029 lux and using 10 m-long guide. The overall efficiency of the daylight system was around 3.4%, a low value presumably caused by the large number of components and optical couplings, and the inefficiency of the side emitting diffuser.

2.3.4 Solar Canopy Illumination System (SCIS)

This facade mounted system collects sunlight using an Adaptive Battery Array (ABA) - a grid of thin 16 cm square mirrors located inside a weather-proof enclosure with a transparent front window [13]. The façade unit is 3 m wide x 1.2 m high and is connected to a 1m high duct which extends some 9 m into a building. The orientation of the mirrors changes with sun position and the light is concentrated and redirected by lenses and mirrors into the rectangular cross section 'dual function prism light guide'. Electric light is from fluorescent T5 lamps located inside the guide. The guide inner surfaces are lined with multilayer optical film (MOF) which has high reflectance at all angles, and optical lighting film (OLF) which reflects light preferentially. Sunlight travels along the guide using total internal reflection within the MOF until hits an extractor material made of OLF.

This diffusely reflects the light and the portion that no longer meets the angular conditions for total internal reflection exits the guide via the bottom surface. The control system uses DALI controlled ballasts, in addition to light sensors, to maintain the desired interior illumination level. A prototype at the British Columbia Institute of Technology shows that about 25% of flux incident on the mirror array arrives on the workplane extending 9 m from the façade.

 HSL collector	 HSL luminaire
 UFO collector	 UFO luminaire
 SCIS	 Parans collector

2.3.5 Fibre Optic Solar Lighting System (Parans)

The system, developed commercially by Parans Solar, uses roof or façade mounted 1 m^2 modular solar panels containing 64 No Fresnel lenses [14]. Each lens is able to track and concentrate sunlight into a 0.75 mm diameter optical fibre. Sixteen fibres are combined into a cable each of maximum length 20 m. The tracking is controlled by a microprocessor which is continually fed information from a photo-sensor which scans the sky to detect sun path. The system learns and remembers the sun path at any location and thus can be moved without pre-programming. The system has five luminaire types, three of which are hybrid luminaires equipped with fluorescent lamps which dim automatically depending on sunlight conditions. Manufacturer's data for an installation with 10m optical cable and direct solar illuminance of 75 klux quotes a luminaire flux output of 7500 lm and 10000 lm for a 4 m cable. This corresponds to a system efficiency of around 30% and 40% respectively. The system has optimum collecting hours when the solar panel is within an angle of 120 degrees of the sun.

3 Evaluation and discussion

The above suggests that the success or otherwise of systems is related to both the nature of the technology and to the interaction of the lighting with the building. This section addresses these issues.

3.1 Light delivery

Table 2 summarises some aspects of HLS performance. Quantity of daylight delivered depends on system type, its method of use and the solar resource. Overall system efficiency is a function of the individual optical elements used and the optical processes linking them. The UFO system, which has a notably low overall efficiency, consists of two separate guidance systems for daylight and electric light, each with two optical couplings. The diffusing output device alone accounts for 25% of total losses. By comparison the HSL, which is some 20 times more efficient, has only one light guide and light output devices for both sources contained within a mirrored luminaire. Thus simplicity appears to be a virtue in system configuration. As in any lighting system the location of the hybrid output devices has a major bearing on light delivery. For working areas where good distribution of light is important, those systems having a number of discrete output devices (e.g. HSL) or large area sources (e.g. SCIS) are likely to perform better than those having large linear sources such as Arthelio. HSL and UFO use modified off-the-shelf luminaires as output devices but Parans uses a specially constructed hybrid luminaire. All have light outputs of the order of 3000- 6000 lumens – comparable to that of electric luminaires used in offices - given optimal sunlight conditions. These are all greater than those of measured discrete TDGS output devices set out in Reference 2 because, firstly, TDGS are usually smaller (typically 300 mm diameter or 600 mm square) and, secondly, the TDGS outputs quoted were largely for overcast conditions.

There are a number of concerns relating to the delivery of electric light via hybrid systems. The first is the sub-optimal optical processes within the luminaires - the optics necessary for electric sources need modification to accommodate the daylight emitters and vice versa. A second concern relates to electric lighting control. In Western Europe for example, where cloudy skies predominate, daylight illuminance may fluctuate throughout the day, placing unusual demands on the control system and potentially affecting lamp life.

The quality of light from hybrid devices, notably HSL and Parans equipped with luminaire optics is superior to that of the basic diffusers used in TDGS. Also the proximity of electric and daylight sources within the luminaire may mask gross differences in colour appearance. To extend this idea there is potential for the use of colour changing electric sources in hybrid devices to mimic changes in daylight colour, although this has not yet been realised.

TDGS have been demonstrated to work in both sunny and cloudy latitudes,but it is not evident that systems based on sun tracking will consistently deliver adequate amounts of light in, say, Northern Europe. The author measured approximate luminaire flux output on a Parans system in Southern England having a south facing collector mounted at 30^0 to vertical, and with a 20 m cable. Luminaire output was 15000 lumens for direct sun (98000 lux normal to the collector), but only 50 lumens for a cloudy sky (10000 lux).

Some idea of the utility of the various systems may be gained by attempting to use each in turn for a nominally similar arbitrary task – to provide 2% ADPF+ADF across the workplane of a 12 x 12 x 3 m windowless space. Clear sky and sun were assumed and to ensure uniform illuminance discrete output devices were at 1:1 spacing to height ratio. The system configurations would be as follows:

Using daylight guidance technology:

- Sixteen 250 mm-diameter TDGS each comprising collector, guide and output device.

Using HLS:

- One HSL system comprising one collector and 16 luminaires.
- Sixteen UFO systems each comprising a collector and a luminaire.
- Three Solar Canopies are enough to provide ADF of 3%, but four systems are required to provide a reasonably uniform illuminance level.
- Fibre optic solar lighting system (Parans) comprising four solar panels and 16 luminaires.
- One Arthelio system comprising one collector and two guides will provide ADF of 2.8% using electric lighting only:

16 triple F14W/T5 fluorescent luminaires would give an equivalent illuminance.

It is clear that although the numbers of discrete luminaires/output devices are similar for many of the specifications, the number of collectors and guides differ markedly. Thus a wide range of equipment may be used to give a nominally similar result.

3.2 Cost and value

Whole life cost calculations for a lighting system include both initial and running costs. Costs may be offset by savings including reductions in electricity consumption by daylight substitution, reduction in cooling loads, and reduction in electric lighting maintenance costs. An indirect financial benefit may be the value of improvement in well-being and productivity of occupants due to daylight, although this is difficult to quantify. There is some published information on capital cost of HLS systems but there is little accumulated experience of running costs so attempts to compare system costs need to be treated with caution.

It is evident that capital costs of HLS systems are generally more expensive than electric lighting, but comparable to TDGS for two storeys or above. Before conclusions can be drawn about long term costs, the issue of running costs must be addressed. Electric lighting is dominant both visually and economically in the majority of buildings that have been equipped with daylight guidance to date, given that electricity is the major running cost. TDGS long term costs only compare with an electric-only alternative only if a series of favourable assumptions about future energy costs and system configurations are made [3]. The suspicion must be that hybrid systems also will provide a poor economic return when viewed solely in cost terms. Cost needs to be balanced by value – principally the benefits of delivered daylight. This suggests that the configuration of a HLS system, notably its ability to provide a ‘day-lit space’, will have a marked impact on long term cost and benefit.

3.3 Relationship with building

The main external architectural concerns relate to collecting devices. Mirrors and lens arrays located on roofs may be visually intrusive and limit other roof uses. They may be large items – for example the Arthelio mirror is 2.5 m diameter - and require protection by additional construction. Façade mounted systems may occupy considerable areas of the building envelope and present problems of appearance and integration. Furthermore systems such as SCIS require at least extra storey height and, potentially, almost dictate that the whole building be designed around them.

Internally all systems require vertical and/or horizontal paths for guides. Those delivering daylight via flexible optical fibre cables require little more space provision than electrical or communications cables and have few implications for interior spatial layout. At the other extreme, enhanced daylight guidance and SCIS require dedicated ducts, through or over several storeys occupying rentable floor area and restricting internal spatial flexibility.

Roof mounted heliostats may require additional structural work to account for wind and dead loads but these are of the same orders of magnitude as equipment such as cooling towers. Façade mounted collectors are structurally similar to cladding. Light transport and distribution elements present no more structural problems than, respectively, ventilation ductwork or luminaires.

The main unique concern of HLS components is fire resistance and to prevention of passage of smoke in both vertical and horizontal transport components. HLS based on light guides may pass through fire compartment enclosures and a range of measures including fire protected ducts, fire dampers and fire-resisting cladding may be required. Façade mounted systems will generally be within one compartment.

3.4 Human response

The literature contains nothing specifically on human reaction to HLS. Human response to TDGS gives some clues about attitudes to daylight delivered via guides or via devices similar to conventional luminaires. Evaluation of the Arthelio installation indicated a general preference for daylight; that detection of changes in exterior conditions was possible; and that it provided bright, glare free light in which the daylight contribution was discerned by its colour properties [15]. User reaction in offices equipped with TDGS and a separate electric system, and some also with windows have been studied. In these the electric lighting was dominant with the guide output making only a modest contribution to task illuminance (the equivalent of 1% ADPF+ADF) [16]. TDGS were considered inferior to windows in delivery of most aspects of daylight quality (notably light distribution and external communication) although satisfaction improved with increased ADPF+ADF.

Iit is possible, therefore, to speculate in general terms about likely human response to HLS systems and some desirable design features. The quantity of daylight delivered needs to be high enough to convince users that it is indeed daylight; the evidence suggesting that an ADPF+ADF in excess of 2% is required for TDGS. Spatial and diurnal illuminance variation, one of the unique properties of daylight, must be accommodated. Clearly façade based systems such as SICS have an advantage in trying to create the appearance of a 'day-lit space'. There is a danger that automatic illuminance 'top-up' will create a uniformly lit space that users will perceive as dominated by electric lighting no matter how much daylight is being delivered. Similarly the perception of diurnal variation apparently requires a user view of a daylight device which is capable of mimicking external illuminance.

The nature of the output devices is important. It is clear that colour is important in user recognition of daylight and thus the proportions of daylight should be such that it is not swamped by the electric component. There is a danger that daylight from 'luminaire-like' devices will be considered as electric light so there is a case for making hybrid luminaires distinct from wholly electric luminaires.

3.5 Design methods

Standardised methods of design calculation, data production and exchange are universal in the lighting industry. Electric and daylight codes set out recommendations for, variously, equipment, illuminance levels and surface properties. Recent work extends this guidance to TDGS [1]. Currently no independent design information exists for HLS to date and manufacturers' websites are the main source, usually offering little more than output device spacing and installation advice. They appear to be based on optimal conditions of the most favourable possible system configuration and assumed daylight resource. Also different methods are used to describe system performance meaning that evaluation of alternatives is difficult. Although most HLS have their origins in academic research, a generic research effort based on accumulated experience of their use has not had time to materialise. A similar exercise for TDGS produced design guidance and norms, and it is to be hoped that this process will be repeated for HLS.

4 Conclusion

Daylight guidance has been one of the major areas of innovation in interior lighting in recent years and HLS is the latest expression of the technology. The innovative nature of HLS means that there are currently only two commercially available systems. As a result there is little accumulated experience of their use. It is likely that the lessons learned from feedback from TDGS installations in respect of design criteria, integration with other lighting systems and the building fabric and economics may be relevant to HLS.

The advocates of daylight guidance advance two main arguments for its use – firstly that they deliver daylight deep into interiors and, secondly, that in doing so energy may be saved by electric light substitution. The evidence to date is that some HLS can under favourable circumstances deliver large quantities of daylight, possibly sufficient to create a 'well day-lit space' as defined by ADF criteria. The light is delivered via luminaires. The evidence from studies of TDGS suggests that under some circumstances light coming out of a guide via a luminaire-like device will not be perceived as 'daylight', particularly in the absence of the other components of daylight notably contact with the exterior. In other respects HLS can potentially deliver better quality lighting than TDGS since the luminaires used have better light control and the possibility exists of colour matching of the dual sources.

HLS represents an advance over TDGS on a number of fronts. They offer the opportunity to transport light deeper into buildings and pose less practical problems, notably in terms of fire precautions. The use of a single output device offers seamless integration of electric and daylight. However this process requires sub-optimal solutions. For example the optics necessary for electric sources may need modification to accommodate the daylight emitters and vice versa. It is arguable that an integrated lighting system with separate output devices may perform better. Most of the HLS have been developed for sunlight sources but are now being marketed in locations where other sky types predominate. The same sequence of events occurred with TDGS and the full implications, in terms of requirements in other locations, have yet to be appreciated. The economics of HLS have yet to be explored. On the limited published evidence they represent substantially greater capital cost than TDGS. The latter have been shown to economic over the long term only if favourable assumptions are made regarding energy costs and the same must apply to HLS.

HLS offers an exciting possibility for lighting practitioners but much work is required to realise this. This includes – study of human response to HLS and development of suitable design criteria; development of design methods; feasibility of use of the various types of daylight guidance in different geographic areas; and the long term economics of such systems.

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DC VOLTAGE LIGHTING SYSTEMS

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Abstract. *The paper presents some general considerations regarding energy distribution in the low voltage dc networks as an alternative to the ac distribution systems. Most applications of direct current occurred as a result of development and growth in importance for techniques used for obtaining electricity using renewable sources. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications. A dc lighting system shows real interest regarding efficiency in lighting applications. Equipment needed to such a system exists in the markets (lamps and lighting fixtures) and in addition, some of them are more efficient than those in alternative power.*

Keywords: *low voltage dc networks, dc lighting system*

1 Introduction

Loads that meet today are very different from those that existed 100 years ago and were mainly represented by resistive loads and electric machines. In the late 1880s, George Westinghouse and Thomas Edison became adversaries due to Edison's promotion of direct current (DC) for electric power distribution over alternating current (AC) advocated by Westinghouse and Nikola Tesla. The latter won this confrontation known as "War of Currents" due to fact that ac distribution had the transmission for long distances advantage. Now the scenario is completely changed because of the the influences of electronic equipments and eir requirements in terms of the electric power supply.

Rapid development of semiconductors made electronic equipments to become dominant as a share of applications for residential buildings and offices; because they use a different voltage level of the network, both in frequency and amplitude, the ariseing issue is the change of the voltage level, respecting the quality requirements. These efforts involve costs and energy losses. Since most electronic equipment used dc voltage, the question arise regarding the use of dc distribution systems instead of ac distribution systems. The dc systems are classified by means of voltage level in High Voltage DC systems (30 kV $<$ U $\leq$ 1 500 kV), Medium Voltage DC systems (1500 V $<$ U$\leq$ 30 kV) and Low Voltage DC systems (U $\leq$ 1500 V). The following is a brief description of Low Voltage DC systems in witch lighting systems may find applications.

2 Low Voltage DC systems [1, 2]

Equipments such as computers, fluorescent lamps with electronic ballast, televisions use dc voltage. They have in their structure a rectifier, which converts the ac voltage into dc voltage. The conversion process introduce in the ac network harmonics which have different negative effects (currents in the null conductor, inadequate protection functioning). Such equipment can be supplied directly to dc voltage. Problems occur for the electrical machine with rotating magnetic field or other equipment, witch, for normal functioning need to be supplied in ac voltage. The supply of the ac loads will be achieved through an inverter witch can supply directly the load or the bus where more loads are connected.

In the context of the new worldwide energy policy, which seeks to take measures to produce electricity using renewable energy sources, a low voltage dc network can interconnect distributed generation units. Moreover, by using renewable energy sources can be obtained directly dc voltage. A diagram of a LVDC network (Low Voltage Direct Current) witch interconects distributed generation units is shown in Figure1.

There are Ultra Low Voltage Direct Current Systems (ULVDC) witch are characterized by a voltage level up to 120 V. In practice, this system is used only in case of electronic equipment for offices and residential buildings.

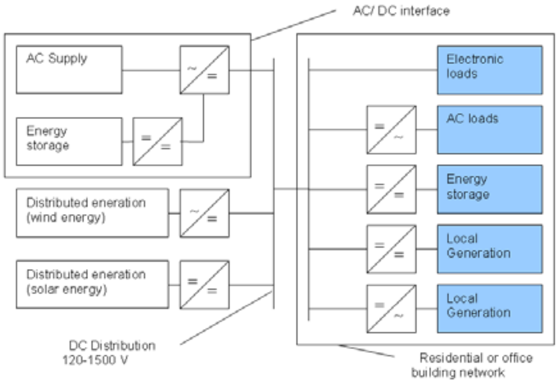
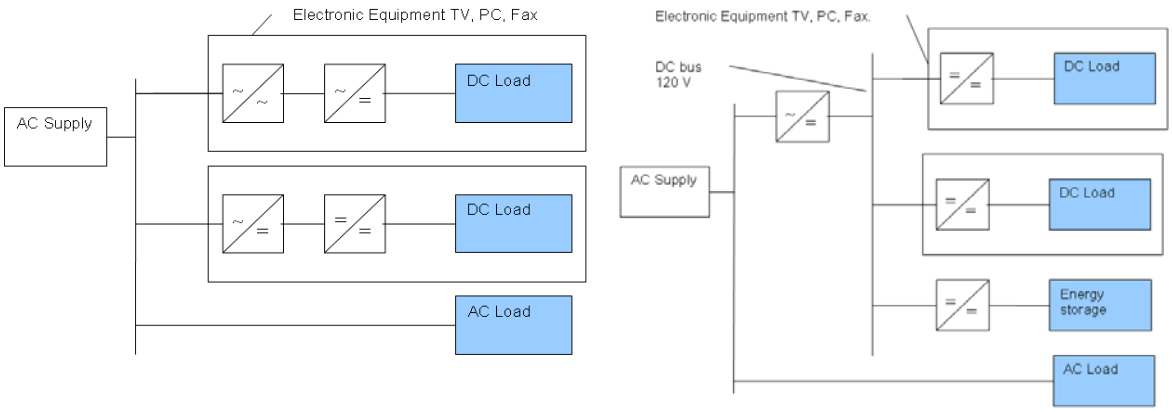


Figure 1 LVDC network with distributed generation units [1]

Lot of equipments have in their composition a rectifier and a transformer which converts and transform the ac voltage to the dc voltage at the necessary operating level (Figure 2a) [2]. Increasingly fewer equipment in these buildings are subject to operation in ac voltage.



a) b)

Figure 2 a) AC voltage Supply and b) AC and DC Voltage Supply [2]

Moreover, most of new electronic equipment have in their composition a transformer followed by a rectifier. The transformer is supplied even when the equipment is in stand-by, therefore, losses occur during the period the equipment is not on. One solution proposed for dc and ac voltage distribution is shown in Figure 2b [2].

By waiving the process of conversion and use a scheme such as that proposed in Figure 2b, the number of converters is reduced compared with the classical solution and when the power losses of the electronic equipment are also reduced. Basically, only one rectifier in needed, located before the dc bus; power sensitive loads can be supplied also through a battery storage.

LVDC networks presents several advantages:

- safety: for human body the dc voltage is not as hazardous as the ac voltage because it dosen't leads to involuntary muscle contractions. The dc voltage must be less than 50 V to avoid this danger to the human body. Moreover, by choosing for the voltage level a sufficiently small value, a completely safe system may be realized in this regard;
- magnetic fields are reduced;
- since for the whole system just one rectifier is needed, we can chose a better quality one (a IGBT based converter) in witch case with a proper control, the impact of electronic equipment in the ac network can be reduced by lowering the harmonic content;
- a converter that allows a bidirectional flow can introduce energy into the ac network when there is a surplus produced in the dc network due to the existence of an increased potential of renewable energy.

3 AC and DC low voltage hibrid systems

Most applications of dc voltage in residential and office buildings occurred as a result of developement in technologies used to produce electricity using renewable sources. Using photovoltaic modules admits dc voltage production. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications.

Although recently technical developments in this area are significant, although there is real potential for such a system to provide energy to a whole facility often a hybrid solution is chosen. There are high power loads (washing machine, air conditioning unit) witch have to be supplied in ac voltage for normal operation. For this reason, in most cases a hybrid energy supply sistem is accomplished (ac and dc low voltage system). Such a system can interconnect the renewable energy sources and allows energy storage in the batterie. Figure 3 presents a simple hybrid system.

4 DC Lighting sources [4]

Lighting is a popular use for renewable energy. There are several methods to achieve a lighting system using dc voltage and establishing the best solution is quite easy even for particular requirements.

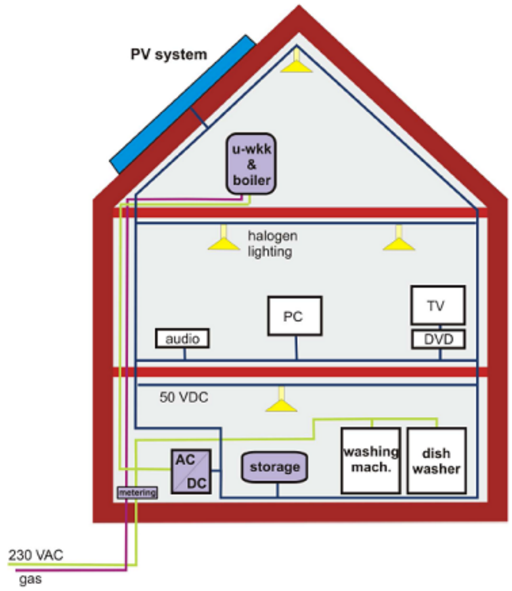


Figure 3 AC and DC low voltage hibrid system [3]

Nearly all lighting systems connected to the public network uses ac voltage for witch the accessories are obtained easily and at relatively low costs. However there are impediments in terms of a ac lighting system using renewable energy sources. First, to be able to use the energy stored by a battery system an inverter needes to be installed. This can significantly increase the overall system cost. Another aspect that can be taken into account is the fact that in some cases, an ac lighting system may be less energy efficient than the one supplied in dc voltage. Since DC lighting can be powered directly from the battery bank, the added expense of purchasing and installing an inverter is not necessary.

The issue is the analysis of the dc lighting solutions available and their possibilities of implementation in terms of reliability. Incandescent lamps, fluorescent lamps, halogen lamps and LED's can be used for indoor lighting.

4.1 Incandescent lamps

Incandescent lamps are some of the cheapest solutions but also some of the least energy efficient. However, incandescent lamps supplied in dc voltage are approximately 30% more efficient than supplied in ac voltage. There are incandescent lamps supplied in dc voltage with a power rating of 5 – 100 W. These lamps can be used in dc and ac voltage by means of the same fixtures (socket, base lamp).

4.2 Halogen lamps

These types of lamps are more expensive than incandescent lamps however, for the same power of the lamp they are 30% more efficient than incandescent lamps. A halogen lamp with a lower power can produce the same luminous flux as a higher power incandescent lamp. Halogen lamps produce a “brighter” light than incandescent lamps. These lamps can be used in the same way as incandescent lamps, directly or with adapters. The fixtures should only be connected to a dc power source.

4.3 Fluorescent lamps

Fluorescent lamps used in a 12 V dc lighting system are generally 3 – 4 times more efficient than halogen or incandescent lamps. Their disadvantages consist in reduced possibilities of fixture choice and components required in a dc voltage system. If for halogen and incandescent lamps you can use the fixtures from ac lighting systems, for fluorescent lamps specific 12 V ballast is required.

While for incandescent and halogen lighting in dc voltage specific lamps are needed, all fluorescent lamps are essentially the same. If an armature is purchased, any fluorescent lamp can be used. An exception is represented by compact fluorescent lamps, where the ballast is attached to the lamp in witch case a special lamp in dc voltage is required.

a) b)

Figure 4 a) 10 – 50 W halogen lamps and b) 15 – 30 W fluorescent lamps [4]

4.1 Light emitting diodes

A light-emitting diode (LED) is a semiconductor diode that emits light in direct polarization of the p-n junction. The effect is a form of electroluminescence. The color of light emitted depends on the composition and the semiconductor material used, and may be in the range of infrared, visible or ultraviolet. A light-emitting diode is small light source, most often accompanied by an electrical circuit that allows the modulation of the light radiation shape. They are used as indicators within the electronic devices, but increasingly more often are used in power applications, such as lighting sources.

Compared with other sources presented, they are three times more efficient than halogen lamps and one of the most efficient ways of transforming energy into light. Light-emitting diodes are a good choice for local applications and with a low illumination level. Due to low consumption, they are viable and economic applications, especially in lighting systems using photovoltaic modules.

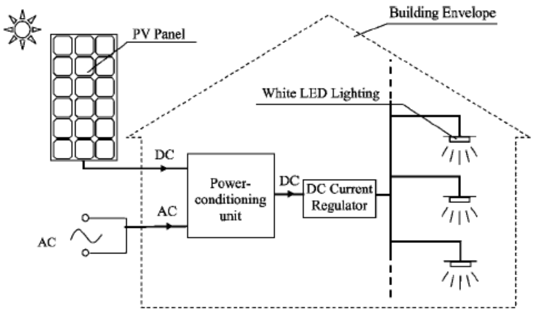


Figure 5 DC Lighting System using LED’s [5]

5 Baterries [6]

Batteries are electrochemical cells that store energy in chemical bonds. If the battery is connected to an electrical load and discharged, the chemical energy is converted to electrical energy. By reversing the flow of current, the battery is restored to its initial state corresponding to the charged condition.

The following is a presentation of some types of batteries that are applicable in the lighting systems using dc voltage produced by photovoltaic modules.

There are different types of flooded lead-acid batteries: lead-antimony batteries, lead-calcium batteries, lead-antimony-calcium hybrid batteries.

The structure of a lead-acid battery is presented in Figure 6.

In these types of applications are also used Captive electrolytic Lead-acid and nickel-cadmium batteries. Captive electrolytic Lead-acid batteries are lead-acid batteries with "captive" electrolyte, which are similar to lead-acid batteries; the difference consists in the semi-solid electrolyte structure (using silica gel). The electrolyte immobilization may also be achieved by its absorption in a fiberglass mat which is placed between the electrodes plates (absorptive glass matting). Captive electrolytic Lead-acid batteries maintenance is low due to the fact that electrolyte gassing is reduced.

In Table 1 are listed some aspects regarding the advantages and disadvantages of this batteries.

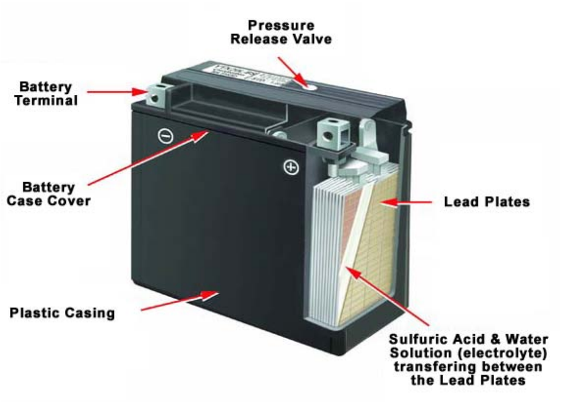


Figure 6 Lead-acid battery structure [6]

Table 1 Advantages and disadvantages of batteries used in lighting systems supplied by dc voltage

Battery Type	Advantages	Disadvantages
Lead-antimony battery	Low cost. Good performance at high temperatures. Wide availability. Good cycle life. Can replenish electrolyte.	High water loss. Require regular maintenance.
Lead-calcium battery	Low cost. Wide availability. Low water loss. Can replenish electrolyte.	Does not ensure proper operation at high temperatures and overloading. Require regular maintenance.
Lead-antimony-calcium hybrid battery	Medium cost. Low water loss. Good performance of the chargind-discharging cycle. Good cycle life.	Limited availability. Require regular maintenance.
Captive electrolytic Lead-acid battery	Medium cost. Medium cycle life. Low ar no maintenance.	Limited availability. No proper operation at high temperatures and overloading.
Nickel-cadmium battery	Wide availability. Low ar no maintenance. Good performance at high/low temperatures and overloading.	High cost. Limited availability.

The batteries main functions in these systems: are to store the energy produced by photovoltaic modules during the day and supply it to the lighting load at night, to supply the loads with stabile dc voltage (no fluctuation) and to establish a suitable operating voltage to maximize the energy produced by photovoltaic system.

For dc lighting systems using photovoltaic modules, batteries are subjected to repeated cycles of charging and discharging. Batteries must resist to these conditions to maximize their performance and cycle life. In such a system, the main operating cost is represented by batteries replacement. Therefore, the battery cycle life has to be as high as possible. Battery cycle life is influenced by several factors like: the assessment conditions in battery design and production, temperature, battery discharge level and discharge frequency, the average charging value, charging methods. From all of the mentioned factors, the temperature has a particular importance: high temperatures leads to electrolyte losses and on the other hand, low temperature extend the battery cycle life but reduce its capacity.

In any application, battery cycle life can be optimized through an appropriate charging (without over-charging and bellow limit discharging), maintaining a high charging level, limiting the discharge level and the discharge frequency, ensuring an average temperature and by following the maintenance program.

6 Conclusions

The paper presents some general considerations regarding energy distribution in the low voltage DC networks in witch lighting systems may find applications. Most applications of direct current occurred due to the development of techniques used to obtain electricity using renewable sources. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications.

In this paper are also presented a hybrid dc lighting system and a dc lighting system using the energy produced by photovoltaic modules. In the case of the hybrid system some loads are supplied by dc voltage and other loads needing ac voltage are supplied from the ac network. Stand-alone photovoltaic lighting systems are independent, fully integrated power supplies with the primary function to operate lighting equipment. They are simple to install, and if properly designed and maintained, can provide years of service.

Important components in stand-alone dc lighting systems using energy produced by photovoltaic modules are the batteries. Some aspects regarding batteries (advantages, disadvantages, life cycle, optimal operating conditions) are presented.

A dc lighting system shows real interest regarding efficiency in lighting applications. Equipment needed to such a system exists in the markets (lamps and lighting fixtures) and in addition, some of them are more efficient than those in alternative power.

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The authors of this paper, Călin GECAN and Radu BINDIU were granted with the Award of the Ph.D. Students Best Paper

TEN YEARS OF SUSTAINABLE LIGHTING IN TRANSYLVANIA

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Abstract. *The Lighting Engineering Center at the Technical University of Cluj-Napoca, Romania was established in 1999, thanks to the EU Tempus grant. The main goals are sustainable lighting dissemination and involvement in the lighting labor market (up-date, postgraduate training and PhD students) – http://users.utcluj.ro/~lec. There are two highlights: the "Ingineria Iluminatului" (Lighting Engineering) journal (now at the 23rd number) and the ILUMINAT Conferences (started in 2001 and held every two years in Cluj-Napoca). The ILUMINAT conferences managed to bring in Cluj worldwide specialists and this increased the lighting knowledge in our area. In order to support its activity, the Lighting Engineering Center has participated to several European and national research programs and was involved in major community lighting projects. The European programs topics were in the area of energy efficient residential lighting - EnERLIn, energy efficient buildings - NAS-Enerbuild, Daylight. In the lighting projects (high-school, district lighting in Cluj, Dej and others), the main target was on state-of-the-art solutions with accent on energy efficiency. Also, LEC members have been participated to all major lighting conferences and established links with the lighting community in last years. The paper presents some interesting results of LEC research in the above mentioned European programs and lighting projects.*

Keywords*: lighting engineering, education, European programs, energy efficiency*

1 Introduction

The last decade has seen many improvements in curricula and teaching methods in Romanian universities. The building sector, particularly that of civil buildings, shows promising prospects of future development. In the last years, many projects were and are financed by the World Bank, BERD (European Bank for Reconstruction and Development) PHARE and ISPA programs to improve or refurbish the water supply network in many Romanian cities, the buildings thermal insulation of the buildings, to enhance the thermal energy savings, to improve the quality of the environment. There is a great demand for up-to-date technology and know-how for a resource-conscious building, renovation and energy planning.

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). The global electric lighting energy use may be split in four sectors: services 48%, residential 28%, industrial 16% and street lighting and other 8%. Lighting systems design trends are dynamics both in time and between countries. The recommended illuminance level represents only one of the design parameters, but it is determinant for a lighting system and its energy consumption.

Lighting electricity consumption accounts for about 20 to 30% of the total energy required by an office building. On average, the investment cost of lighting facilities for an office building works out at around 1 to 2% of total investment. The power density for standard fluorescent lighting installations varies from 13 to 20 W/m^2. Recent progress in equipment and design demonstrates the possibility to reduce these values in the range of 7 to 10 W/m^2.

Savings will vary by country, depending on existing baseline conditions. Energy saving measures in lighting must be accepted by the users and must be associated with an improvement of their standards working condition, having in mind even the fact that the annual lighting consumption of an office worker is of the order of one hour of the his/her salary cost.

2 The Lighting Engineering Centre LEC

The Lighting Engineering Centre **LEC** was founded in April 2000 at the Technical University of Cluj-Napoca, following the accomplishment of the CME-03551-97 Tempus-Phare project *Lighting Engineering Centre – LEC – an excellence centre for consultancy and continuing education in the lighting field in direct link with the needs of the labour market".* This project, developed between December 15, 1998 – March 14, 2000, concentrated the efforts of university professors from Cluj-Napoca, Barcelona, Helsinki and Naples.

Figure 1 Professors Ramon San Martin Paramo and Florin POP

The main objective of LEC was and is to create a regional pole of interest in lighting in the North-Western region of Romania, linked with the needs of the labour market and the improvement of the educational curricula. Here continuous formation in the lighting field is being provided by seminaries and workshops, short postgraduate courses dealing with the Management of Electric Installations and Lighting, research studies on modern, energy efficient lighting systems, bi-annual International Conference ILUMINAT (starting with 2001), editing lighting journal Ingineria Iluminatului (Lighting Engineering) journal – the Romanian scientific journal in lighting field, half-yearly edition, summer courses. The Lighting Engineering Centre concludes the work developed at the Technical University of Cluj-Napoca in the area of lighting education and research.

Dr. Florin POP was invited to participate at the International Seminar Advanced Daylighting and Electric Lighting Systems in Architecture, 9–22 October 2003.

Figure 2 ILUMINAT 2001, Opening Lecture of Prof. Ir. Wout van BOMMEL, CIE President

Figure 3 In 2001, together with BEST (Board of European Students of Technology) office of the Technical University was developed a European Summer Course "Light & Lighting, Ambience, Management and System" with the participation of 21 students from Europe. The course presentation and the written support were performed in English.

The Seminar was organized by the Light & Architectural Environment Laboratory – LAEL, Kyung Hee University, Seoul, Korea, director Prof. dr. Jeong Tai KIM. Professor Florin POP presented the conferences "Recent Research Trends on Advanced Daylighting System", for the Master students in Arhitecture and "Lighting in Eastern Europe: A Romanian Case Study", for LAEL members. Two agreements for university cooperation were signed: The Memorandum of Understanding between the College of Architecture and Civil Engineering, Kyung Hee University, Korea, and the Universitatea Tehnică Cluj-Napoca, Romania (signed by Prof. Florin POP on behalf of the Rector of UTC-N) and The Memorandum of Understanding between Light & Architectural Environment Laboratory, Kyung Hee University and Lighting Engineering Center, Universitatea Tehnică Cluj-Napoca.

Figure 4 Professors Inhan KIM (chairman, major in Architecture), Jeong Tai KIM (director of LAEL), Florin POP, Byung Ik SOH, Dean, Hee-Cheul KIM, Sun Kuk KIM (chairman, major in Architecture)

3 Lighting projects

LEC was involved in several interior and public lighting projects, and the red line was to propose high quality and energy efficient solutions, and also to sustain the activity of the center. LEC have worked only for City Councils and Cluj Universities.

3.1 Rehabilitation of pedestrian lighting in residential districts of Cluj-Napoca and Dej

The public lighting for pedestrian pathways or for mixed traffic pedestrians/vehicles between blocks of flats was made in the same time with the urban structure. For this reason the lighting system was designed and installed between 1960-1990. The existing system presents many deficiencies and cases of destruction, determined by vandalisms, physical and technical use, inadequate protection, and low quality of lighting equipment.

The City Council Of Cluj-Napoca initiated, in May 2004, a study conducted by the Lighting Engineering Center of the Technical University of Cluj-Napoca for the rehabilitation of pedestrian lighting in two residential areas of our city: Grigorescu and Gheorghieni districts. The other areas were studied by the Romproiect Electro Company. A similar project was conducted for the Dej district Dealul Florilor.

The aims of these studies were: a) to survey the existing situation; b) to present the new European and national regulations concerning this matter; c) to propose a modern energy efficient system, and d) to generate specific GIS maps of the whole lighting system and electric network.

Our students have been involved in the survey in order to determine: a) position and type of luminaries; b) columns types, lamps, electrical boxes, c) areas with special maters. Proposals for a modern lighting system were targeted to obtain a high quality photometric environment and energy efficiency. The design was based on the quality requirements stipulated on the Romanian norms NP 062-02 and SR EN 60598 and European or CIE guidance. For instance, the proposed systems on the Grigorescu district will use an installed power 20,493 W instead of the used power 3,062 W of existing old lamps.

The LEC has proposed a GIS system, based on the maps received from Map Office of the City Council, using AutoCAD software from AutoDESK. The following attributes have been allocated to each light point: district, column identification number, column type and height, lamp type, luminaire type, functional status, date of luminaire mounting, date of last lamp replacement, electrical box characteristics. The GIS map and technical audit of the lighting installation offer to the Cluj-Napoca municipality a very useful database for a well-preservation of the facilities of this public utility and for the further development of the necessary maintenance service.

An important aspect was related to avoiding the light pollution. The luminaries are mounted on the top of the columns, four meters tall. The distribution of the light is rigorously directed to the pedestrian area, to illuminate only the pathway in their immediate surround.

3.2 Interior lighting

LEC was involved in the projects for “Nicolae Balcescu” High-School and for UBB Academic College and Swimming pool. For all three community buildings, we have choose efficient and state-of-the-art solutions in order to create models for other local projects.

The “Balcescu” high-school, built in 1879, changed during time from gas lighting to electric lighting but without lighting quality (illuminance under 100 lx, low colour rendering and flicker). A brand new lighting solution was created on 2005, with T16 lamps, electronic ballast and asymmetrical blackboard lighting and direct/indirect general lighting, in respect to CIE regulations.

The owner requested for a very flexible of the main hall to adapt easily for different events: concerts – static lighting, conferences, meetings, PhD presentations – dynamic lighting. For this reasons it was necessary to adopt a lighting control system, efficient and economic. As the concert hall use an indirect lighting system, with very long coves, it was compulsory to use T16 lamps (class "A" of energy efficiency) with dimmable electronic ballasts.

The Academic College Hall lighting system did not alter the building spirit. The newest solutions were used there, some of them for the first time in Romania.

3.3 LEDs issues

From many different points of view, the LEDs issues are similar to those of early CFLs. There were great expectations and high prices with quality problems. As well, it took more than 10 years to have a stable CFLs market.

Since 2007, several projects have been started in Cluj-Napoca based on LEDs' long-life, small dimensions and alleged energy efficiency.

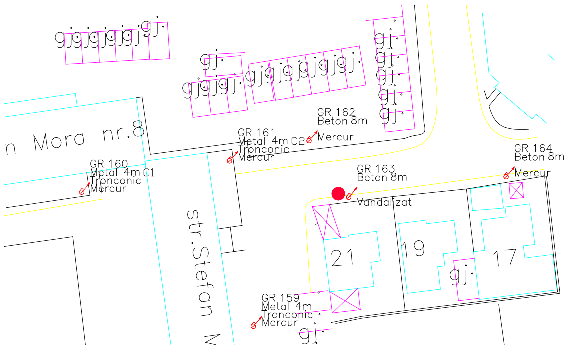

Figure 5 GIS maps for district lighting

Figure 6 "Balcescu" High-school before (left) and after (right) rehabilitation

 

Figure 7 The Main Hall lighting system

These projects have been mostly targeted on exterior architectural lighting, rather than on interior lighting. Few LED databases were originally available, so the lighting systems design has been based on software imagery or *in-situ* trials.

A few conclusions may be drawn after the development and installation of lighting systems for two squares and several buildings in the city of Cluj:

- excellent solution on color lighting, even if limited to new buildings;
- this solution has raised problems for historical buildings (color rendering, LED floodlight too close to buildings and all building imperfections revealed by light);
- a higher number of luminaries have to be used for a building, compared with metal-halide solutions;
- higher investment costs as compared to traditional lighting systems;
- exterior cabling on historical building is problematic;
- luminaire orientation is essential.

Based on our own projects and experiments, we may conclude that formation of LED-trained lighting designers is necessary for the success of future high quality lighting projects. Strong cooperation with architects is compulsory.

4 Programs promoting lighting energy efficiency and energy saving measures in residential buildings

The Lighting Engineering Center of the Technical University of Cluj-Napoca, Romania was recently involved in two programs for promoting lighting energy efficiency and energy saving measures in residential buildings: EnERLIn European Efficient Residential Lighting Initiative, an EIE-SAVE program to promote Compact Fluorescent Lamps in the residential sector, and CREFEN – Integrated software system for energy efficiency and saving in the residential sector, a Romanian CEEX (Excellency in Research) program.

The Questionnaire and Promotional campaign to promote the compact fluorescent lamps (CFL) use in residential area was developed on four levels, by the UTC-N - Lighting Engineering Center - with the support of three partners of the programme: ELECTRICA Distribution Local branch, on a volunteer cooperation, and EnergoBit and PRAGMATIC Compress electric dealers, on the sub-contractual basis. The whole average number of the CFLs is **2.86 units** per people (family, house), received from 8 questionnaire campaigns (7 EnERLIn, 1 CREFEN), 892 people/ houses, 2551 used CFLs, November 2005 – May 2008. The CFLs distribution power in Western Romania is presented in the Figure 8, as a result of UTC-N EnERLIn Questionnaire Campaigns, during the period of November 2005 – May 2008. Favorite powers for CFLs are 13 W and 20 W.

The luminaires equipped with CFLs with increased energy efficiency currently have a large development. In the frame of the EIE-EnERLIn program, a selection of the most representative luminaires dedicated to CFL use has been realized – see Figure 9.

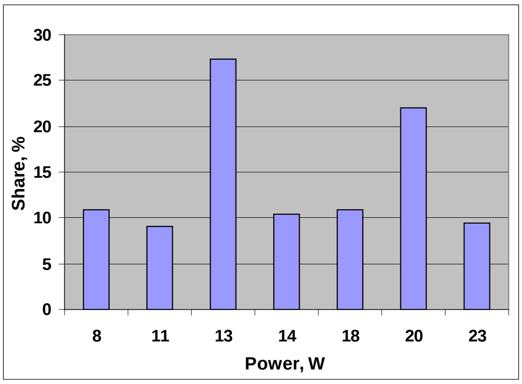

Figure 8 CFL distribution power in Romania
597 households, 1988 CFLs, 2005-2008

Figure 9 Ten most representatives luminaires dedicated to CFL use

Most residential users are less knowledgeable of technical (qualitative and quantitative) and economical aspects concerning (a) real contribution of lighting for energy consumption; (b) energy efficiency of lamps; (c) quality of the obtained lighting. The general conditions of illumination inside a room are the result of combining the quality of the desired lighting with the photometrical characteristics of the furnished room (for example, the sizes and shape of room, the reflectance of the room surfaces). Among the factors characterizing room lighting we mention the photometrical characteristics of luminaires and their setup. The study realized by the Lighting Engineering of the Technical University in Cluj-Napoca in the frame of the CREFEN research program presents the selection parameters of a luminaire to be considered for the residential sector, the thresholds for the increase of use of energy efficient lighting in newly built households, the requirements concerning the integration of compact fluorescent lamps in the design of residential luminaires. In the case of the design of interior lighting installations we have to consider a series of principles and methods relevant to energetic efficiency. A simple software application allows any user with minimal knowledge of information technology to design the lighting installation in his/her own household based on energy efficiency criteria.

A relatively recent study establishes that lighting for kitchen, living room, bathroom and exterior areas consumes approximately 50% of the total lighting consumption. 25% of the lamps installed in households consume 75% of the total lighting energy. Approximately 20% of energy is consumed by portable luminaires, powered through wall outlets.

The analysis of CREFEN program reply sheets (November 2005) on a total of 290 households has shown that the installed power for lighting in the analyzed households has an average value of 853 W - Figure 10. With an average surface per home of 37.39 m^2, (CREFEN - phase report 2005) we obtain an average specific installed power of 22.81 W/m^2, with a preponderant incandescent lighting.

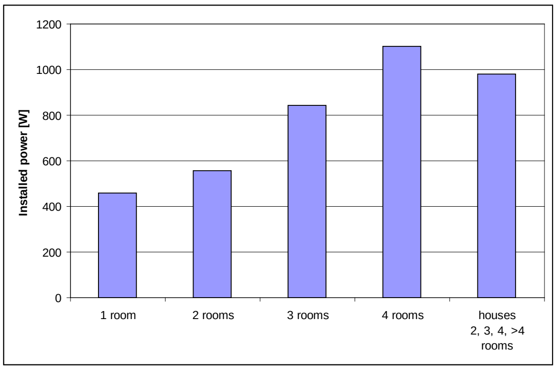

Figure 10 Average installed power for residential lighting - source CREFEN

5 Lighting education

Our basic activity is to teach one semester of lighting for 3rd year in Building Services Faculty. This involves more the basic of lighting technology and design and a small lighting project using Dialux. Lighting education was the first step in preparing new generations of lighting specialists. From 1998, LEC launched the six weeks postgraduate courses in Lighting

Installations Management which include architectural and management chapters, beside lighting. Till 2000 we manage to prepare 30 professionals in lighting. In 2001 we supported a European summer course on lighting with BEST (Board of European Students of Technology) organisation.

We also should mention the organization of ILUMINAT Conferences, started in 2001. These conferences provided the opportunity to the people to listen to excellent presentations from speakers from all over the world and rise debates on various subjects. Speakers like (alphabetical order) Wout van BOMMEL, David CARTER, Luciano di FRAIA, Liisa HALONEN, Koichi IKEDA, Jeong Tai KIM, Janos SCHANDA, Axel STOCKMAR (which attended all conferences) and so many others enhanced the level of interest on events and, together with Romanian participants, managed to make an excellent place to exchange ideas and strength the lighting community.

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ENERGY EFFICIENT RAILWAY LIGHTING ACCORDING TO EN 12464-2

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Abstract. *The European Standard EN 12464-2 "Lighting of work places - Part 2: Outdoor Work Places" specifies the lighting requirements for the lighting of many outdoor areas, tasks and activities - including railways and tramways - and their associated surrounding areas in terms of quantity and quality. Furthermore the standard sets limits of obtrusive light for exterior lighting installations which are based on publication CIE 150:2003. Lighting levels are given in terms of average maintained illuminances of task and surrounding areas. In terms of energy efficiency this standard offers for the first time the possibility for the application of adaptive lighting as for a number of tasks the requirements are dependent on risk, duration, or passenger volume. For the calculation of illuminances and uniformities the maximum grid cell sizes can be evaluated using a formula which takes into account the actual dimensions of the area under consideration. The glare directly from the luminaires of an outdoor lighting installation is determined using the CIE Glare Rating (GR) method described in publication CIE 112:1994.*

Keywords: *railways lighting, energy efficiency, European standards*

1 Introduction

The European Standard EN 12464-2 "Lighting of work places - Part 2: Outdoor work places" [1] specifies the lighting requirements for the lighting of many outdoor areas, tasks and activities and their associated surrounding areas in terms of quantity and quality. In a comprehensive table requirements are given for the exterior lighting of railways and tramways. For the lighting of open and covered platforms the lighting requirements are specified dependent on the type of train services and on the number of passengers [1] which offers the possibility to introduce adaptive lighting systems [2].

The standard specifies lighting requirements for outdoor work places which meet the needs for visual comfort and performance; they do not specify lighting requirements with respect to safety and health of workers at work, although the lighting requirements as specified usually fulfil these safety needs.

2 Lighting design criteria

The main parameters determining the luminous environment are the luminance distribution, the illuminance level and uniformity, the limitation of glare, the directionality of light (modelling), the colour appearance and colour rendering, and the degree of flicker [1]. The luminance distribution in the field of view controls the adaptation level of the eyes. A well balanced luminance distribution (sudden changes should be avoided) is needed to increase the visual acuity, the contrast sensitivity, and the efficiency of the ocular functions. The illuminance and its distribution (on task and surrounding area) have a great impact on how quickly, safely, and comfortably a person perceives and carries out a visual task. The illuminance values specified in the standard [1] are maintained illuminances over the task area on the reference surface, which may be horizontal, vertical or inclined. The task area is defined as the partial area in the work place in which the visual task is carried out. For places where the size and/or the location of the task area are unknown, the area where the task may occur is considered as the task area. The maintained illuminance of the surrounding area shall be related to the maintained illuminance of the task area and should provide a well-balanced luminance distribution in the field of view. For task area illuminances of 100 lx or above the illuminances of the surrounding area are specified as four steps down on the recommended scale of illuminances which was taken from the European standard EN 12665 “Basic terms and criteria for specifying lighting requirements” [3]. The surrounding area is regarded as a strip surrounding the task area in the field of view. The width of this strip should be at least 2 m, but this is usually of no importance for railway or tramway lighting.

Alongside the average maintained illuminances specified for a large number of areas, tasks and activities there are also requirements given concerning uniformities (minimum/average) - and in particular for railway and tramway lighting diversities (minimum/maximum) - [1] for task and surrounding areas. For the calculation and verification of illuminance values (minimum, average, maximum) a grid system has to be used which is based on a formula giving the maximum grid cell size dependent on the area dimensions. This formula is equivalent to the equation given in the European standard EN 12193 “Sports lighting” [4].

The colour qualities of near-white lamps are characterised by the colour appearance of the lamp (warm, intermediate, cool) and the colour rendering capabilities expressed in terms of the general colour rendering index R_a. This methodology is the same as used for the lighting of indoor work places [5]. For the recognition of safety colours the light sources shall have a minimum colour rendering index of 20; for specific tasks, areas or activities including railways and tramways minimum general colour rendering indices are given in the schedule of lighting requirements [1]. To highlight objects, to reveal textures or to improve the appearance of people (modelling), directional lighting may be suitable. Modelling is the term used to describe the balance between diffuse and directional light; too directional lighting will produce harsh shadows. Lighting from specific directions may reveal details within a visual tasks, increase their visibility and making the task easier to perform. Unfortunately there are no measures given in the standard [1], only verbal descriptions.

3 Evaluation of glare

Glare is the sensation produced by bright areas within the field of view and may be experienced either as discomfort or disability glare [1]. The glare directly from the luminaires of an outdoor lighting installation shall be determined using the CIE Glare Rating (GR) method according to CIE publication 112:1994 [6]. For a given observer position and a given viewing direction (2º below the horizontal) the degree of glare is dependent on the equivalent veiling luminance produced by the luminaires and the equivalent veiling luminance produced by the environment in front of the observer. The veiling luminance caused by the lighting installation is calculated according to the Holloday formula. The veiling luminance of the environment is approximated; i.e. it is assumed to be 3,5% of the average luminance of the area under considerations [6]. If no particular observer positions and viewing directions are specified, the glare rating should be computed at the illuminance grid positions at 45º intervals radially about the grid points with the 0º direction parallel to the long axis of the task area [1]. On platforms observers should be positioned in a regular grid covering one or several luminaire spacings with viewing directions along the platform and at ±15° / ± 30° against the long axis.

Regarding the disability glare possibly experienced by vehicle drivers there are no limits specified in the standard [1]; it only states ‘avoid glare for vehicle drivers’. If the situation of a train driver e.g. entering a station is considered to be similar to the position of a car/lorry driver moving along a road, the threshold increment concept - usually applied in road lighting - could be used to evaluate the disability glare. For a given train driver position (midst of a track at a specified height) the veiling luminance can be calculated, and using the average track luminance as the adaptation luminance (next to a platform as 10% of the average platform luminance) the threshold increment could be determined. It has been proven that installations with luminaires suitable to minimize also the light pollution will produce threshold increments smaller than 15% [7].

4 Obtrusive light

Obtrusive light is defined as light, outside the area to be lit, which, because of quantitative, directional, or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information. The time after which stricter requirements (for the control of obtrusive light) will apply, often a condition of use of lighting applied by a government controlling authority, e.g. the local government, is called curfew [1][8]. To safeguard and enhance the night time environment it is necessary to control obtrusive light which can present physiological and ecological problems to surroundings and people. To evaluate the effects of obtrusive light from outdoor lighting installations the methods described in CIE Publication 150:2003 [8] have been included in the standard [1] for the lighting of outdoor work places. For the different environmental zones E1 to E4, i.e. natural, rural, suburban, and urban, limits are specified for pre- and post-curfew hours in terms of maximum vertical illuminances on properties, of maximum luminous intensities of individual light sources into potentially obtrusive directions, of maximum average luminances of facades and signs, and of maximum upward light ratios. Furthermore the maximum values of threshold increments for users of nearby roads are considered.

Railway stations are located in all of the different environmental zones E1 to E4. Using luminaires for direct illumination at relatively low mounting heights (and no high pole lighting) will not cause problems in terms of vertical illuminances on buildings, of luminous intensities in potentially obtrusive directions, and of the proportion of the luminous flux emitted above the horizontal. The possible reduction of light levels dependent on passenger volume [1, 2] - sometimes even switching off during hours of guaranteed non-operation of trains - is a further measure to reduce light pollution particularly in dark (natural zone E1) or low brightness (rural zone E2) areas. Application of energy efficient lighting systems using lamps with higher efficacy, ballasts with lower losses, and luminaires providing higher utilization factors platform will also help to reduce pollution, obtrusive light, and sky glow.

5 Lighting Requirements for railways and tramways

In the schedule of the lighting requirements a large number of areas, tasks, and activities are listed including airports, building and industrial sites, harbours, parking areas, petrochemical industries, power and water plants, railways, saw mills, and shipyards [1]. The requirements for railways and tramways are specified in part 12 of table 5: "Lighting requirements for areas, tasks, and activities". For the specific areas, tasks, and activities requirements are given in terms of average maintained illuminances, uniformities, glare rating limits, and colour rendering indices. For open platforms e.g. there are three different levels of requirements dependent on the type of train or services and on the number of passengers, with a fixed minimum colour rendering index R_a of 20; for covered platforms there are two different levels of requirements dependent on the type of train or services and on the number of passengers, with a fixed minimum colour rendering index R_a of 40. In addition special attention has to be paid to the edge of the platform and to the avoidance of glare for train drivers. The listed minimum values of illuminance, uniformity and diversity [1] are a kind of harmonized average values reflecting current European practice. The dependence of the lighting requirements on the type of train or service and passenger volume gives great flexibility and allows e.g. for a reduction of the illuminance level at night time when only a small number of passengers are expected under nominal condition. As the recommended illuminances for the tasks are given as maintained illuminances the design should take into account an appropriate maintenance factor. The maintenance factor to be applied depends on the characteristics of the lamp and control gear, the luminaire, the environment, and on the maintenance programme. For the elaboration of a maintenance schedule it is recommended to follow the methods described in the CIE guide on the maintenance of outdoor lighting systems [9].

6 Energy efficiency of platform lighting

Lighting requirements in general concern the quality criteria illuminance level, luminance distribution, glare limitation, modelling, colour appearance, and colour rendition. Besides these photometric criteria special attention is paid to the costs of acquisition, installation, maintenance, and operation of the lighting system. Here it is of particular interest to what extent the total costs could be reduced by utilizing lamps with higher efficacy, ballasts with lower losses, and luminaires with higher light output ratios and/or more appropriate luminous intensity distributions The ratio of the achievable illumination level, expressed in terms of an average illuminance on a reference surface (the platform), to the necessary electric power depends on the selected lamps, ballasts, and luminaires as well as on the luminaire layout. For lamps and ballasts there are appropriate measures, efficacy and ballast-lamp circuit power respectively, which serve as a basis for the evaluation of energy efficiency. However, for luminaires the obvious measure, the light output ratio, is not a suitable quantity, as there exists no relationship to the achievable illumination level [10]. The energy efficiency of a particular luminaire in a given layout can be evaluated using the utilization factor platform (UFP). The utilization factor platform is defined as the ratio of the total flux received by the reference area of a platform to the total lamp flux of the installation. If the value of the utilization factor platform is close to the light output ratio of the luminaire there is the risk that the uniformity limits are not met and/or the illuminance along the platform edge is insufficient. Values of the utilization factor platform small compared with the light output ratio of the luminaire indicate not only a poor performance but also the tendency to a higher light pollution as a larger amount of the luminous flux is spread around and not concentrated on the area to be lit. For the selection of appropriate luminaires – covering all requirements concerned – a comprehensive platform lighting design table could be regarded as a useful design tool (Figure 1).

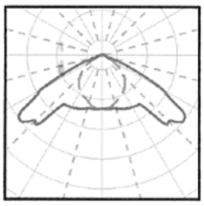
7 Adaptive platform lighting

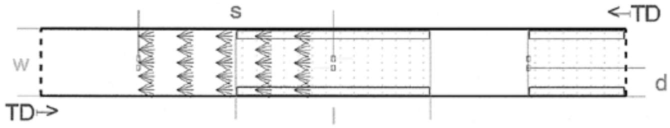
For the lighting of open and covered platforms the lighting requirements are specified dependent on the type of train services and on the number of passengers [1]. This means firstly, the lighting levels could be different for a number of platforms of just one station, and secondly, the illumination levels could be reduced during some of the hours of darkness when only a small number of passengers is being expected [2]. According to the internal recommendations of the German Railways a small number of passengers is defined as less than 500 passengers per day per station [11]. It is important to note that - while reducing the average illuminance levels - the other quality criteria, especially the uniformity and the diversity (as given in Table 1), have to be observed and fulfilled. According to the specified average maintained illuminances it is possible to reduce the lighting level between 25% and

50% and the electrical power between 15% and 50% depending on the type of the adaptive lighting system. If the lighting installation of a covered platform consists of e.g. two roof mounted rows of fluorescent luminaires along the edge of the platform, it is possible to reduce the lighting level (from 100 lx to 50 lx) by simply switching off every second lamp or luminaire. Depending on the luminaire layout it may be impossible to meet the even less strict requirements concerning uniformity and/or diversity. This could be overcome by switching off every second luminaire in a zigzag mode. To double-check the different options, the platform lighting design table could be used again (Table 1). A similar procedure could be applied to HID installations of covered platforms. For open platforms, where a reduction from 50 lx to 20 lx or from 20 lx to 15 lx is envisaged, is seems to be impossible to achieve the required uniformities and/or diversities using a switching off method; here adaptive lighting systems with dimming facilities should be applied using e.g. additional ballasts or electronic control gear. All in all the condition dependent requirements for platform lighting specified in the new European standard EN 12464-2 [1] offer the possibility to introduce adaptive lighting systems which, utilizing intelligent controls, could help to save energy and to protect our environment.

Table 1 Lighting requirements for platforms according to EN 12464-2 [1]

Type of Platform	**E_m**	**U_o**	**U_d**	**GR_L**
Open platforms, **rural and local trains, small number of passengers**	15 lx	0.25	0.125	50
Open platforms, **suburban and regional trains with large number of passengers** or **inter-city services with small number of passengers**	20 lx	0.40	0.20	45
Open platforms, **inter-city services**	50 lx	0.40	0.20	45
Covered platforms, suburban or regional trains or **inter-city services with small number of passengers**	50 lx	0.40	0.20	45
Covered platforms, **inter-city services**	100 lx	0.50	0.33	45





Platform Lighting Design Table (EN 12464-2)

Lamp SON-T PLUS PIA 50W (4400 lm) Mounting height h = 6.0 m Tilt of luminaire 10° Maintenance factor = 0.67

w (m) d (m)	s (m)	reference area / central							reference area / endwise			
		Eav (lx)	Uo	Ud	ER (%)	GR	UFP (%)	TI (%)	Eav (lx)	Uo	Ud	ER (%)
5.00 2.00	15.0	28.2	0.77	0.65	91	40	36	7.2	23.5	0.63	0.45	90
	18.0	23.6	0.69	0.50	91	39	36	8.2	21.5	0.46	0.30	90
	20.0	21.2	0.50	0.32	91	39	36	8.8	20.0	0.31	0.19	90
	22.0	19.2	0.36	0.21	90	41	36	9.4	18.6	0.23	0.13	90
	25.0	16.9	0.20	0.10	91	44	36	10	16.7	0.12	0.06	90
6.00 2.50	15.0	27.2	0.71	0.58	85	40	42	6.9	22.6	0.60	0.42	83
	18.0	22.7	0.67	0.47	85	40	41	7.8	20.7	0.47	0.30	84
	20.0	20.4	0.50	0.31	85	39	42	8.4	19.3	0.33	0.19	84
	22.0	18.6	0.36	0.21	85	41	42	9.0	18.0	0.23	0.13	84
	25.0	16.3	0.21	0.10	85	44	42	10	16.1	0.13	0.07	84
7.00 3.00	15.0	26.0	0.70	0.55	78	41	46	6.4	21.6	0.57	0.38	76
	18.0	21.7	0.65	0.44	78	40	46	7.3	19.8	0.47	0.29	77
	20.0	19.5	0.50	0.30	78	39	46	7.9	18.4	0.34	0.19	77
	22.0	17.7	0.35	0.19	78	42	46	8.4	17.1	0.23	0.12	77
	25.0	15.6	0.22	0.10	78	45	46	9.3	15.3	0.14	0.07	78
8.00 3.50	15.0	24.9	0.65	0.49	72	41	51	6.1	20.5	0.53	0.34	70
	18.0	20.7	0.62	0.40	72	41	51	6.9	18.8	0.44	0.26	71
	20.0	18.6	0.49	0.29	72	40	51	7.5	17.5	0.33	0.18	71
	22.0	17.1	0.35	0.19	72	42	51	8.0	16.4	0.23	0.12	71
	25.0	15.0	0.22	0.10	72	45	51	8.7	14.7	0.15	0.07	72
9.00 4.00	15.0	23.8	0.60	0.44	66	42	54	5.7	19.5	0.49	0.30	64
	18.0	19.8	0.60	0.37	66	41	54	6.4	17.9	0.42	0.24	64
	20.0	17.8	0.49	0.27	66	40	54	6.9	16.8	0.33	0.17	65
	22.0	16.3	0.35	0.18	66	43	55	7.4	15.7	0.23	0.11	65
	25.0	14.2	0.23	0.11	66	46	54	8.1	13.9	0.17	0.07	66
10.0 4.50	15.0	22.5	0.56	0.39	61	42	57	5.2	18.5	0.47	0.27	58
	18.0	18.8	0.58	0.34	61	42	57	5.8	17.0	0.42	0.22	58
	20.0	17.0	0.47	0.25	61	41	58	6.2	16.0	0.32	0.16	59
	22.0	15.4	0.35	0.17	61	43	57	6.7	14.8	0.25	0.12	59
	25.0	13.5	0.23	0.10	61	46	57	7.3	13.3	0.16	0.07	60

s ... luminaire spacing (m)
w .. width of reference area, width of platform (m)
d ... distance of luminaire row from edge of platform (m)
h ... mounting height of luminaires (m)
l .... length of reference area (m)
TD. position of train driver
average reflectance of platform surface 0.15
Adaptation luminance has been set equal to one tenth of the average platform luminance

CEN Flux Code 43 86 99 100 77 0 50 75 0

Eav .. average illuminance (lx), maintained value
Uo .... uniformity Emin/Eav
Ud .... diversity Emin/Emax
ER ... ratio (%) of average illuminance of strip at edge of platform (1 m) to average illuminance of reference area (width of platform) in percent
GR ... maximum glare rating
UFP.. utilisation factor platform (%)
TI ..... threshold increment (%)

Figure 1 Platform lighting design table

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Invited Paper presented at the 5th International Conference ILUMINAT 2009, 20 February 2009, Cluj-Napoca, Romania.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

Central Bureau: Kegelgasse 27 – 1030 Wien – Austria

To: Romanian National Committee on Illumination
Attention: Prof. Florin Pop

Esteemed members of the Romanian National Committee and delegates to the ILUMINAT 2009 CONFERENCE

On the occasion of your upcoming conference, allow me to convey to you the best wishes of the CIE. Your conference comes at a trying time for international trade and many national economies. This global crisis has an impact, which affects nearly everybody, including international organizations like the CIE. Several of our important National Committees find it difficult to pay their CIE dues because of an erosion of their traditional membership base, exchange rate fluctuations and other factors.

For this reason, the CIE Board at its last meeting in October 2008, decided to approach the National Committees at the next General Assembly in May 2009 in Budapest (Hungary) to approve wide-ranging changes in the structure and functioning of the organization. These are aimed at further lightening the financial burden of National Committees with regard to membership fees and generating more income through the operations of the CIE Central Bureau in Vienna. While it is not possible to talk about the detailed proposals in this regard before the General Assembly has had a chance to consider them, it is clear that the CIE, like other organizations, has to continually adapt to changing circumstances and cannot afford to be complacent and inflexible.

The subject of your conference, energy issues and the environmental impact of lighting are receiving our close attention at present and remain an important strategic focus.

Other current developments include a shift from the traditional hands-on management role of the CIE Board to a greater role for the professional staff at the CIE Central Bureau in running the day to day activities of the organization under a new, very active and motivated General Secretary. The Board's active involvement in the running of the organization comes from a time, when there was no or only a rudimentary Central Bureau and the Board members in their honorary capacity were forced to make their scarce time available to provide continuity and keep the organization afloat. By leaving the day to day affairs firmly in the hands of the professional staff at the well established Central Bureau in Vienna, the Board will have more time available to do strategic work and for its statutory supervisory role under the guidance of the General Assembly.

It is a further focus of my presidency to formalize the CIE's existing relationships with other international organizations as much as possible. Recent agreements with the International Committee for Weights and Measures (CIPM) and the Professional Lighting Designers' Association (PLDA) are examples of this.

With this short summary of present strategic CIE objectives, I wish you a successful conference and everything of the best for 2009.

Pretoria, 27 January 2009

Franz Hengstberger
President

CIE **COMMISSION INTERNATIONALE DE L'ECLAIRAGE** **CNRI**
COMITETUL NAȚIONAL ROMÂN DE ILUMINAT

UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA
Centrul de Ingineria Iluminatului

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Sustainable Lighting

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09.30 – 10.00	Participants registration
10.00 – 10.20	Messages
	INVITED LECTURES SESSION
	Opening Lecture
10.20 - 10.50	Honorary Professor **Axel STOCKMAR** President of the CIE National Committee of Germany Energy efficient railway lighting according to the European standard EN 12464-2 *HP Axel STOCKMAR has participated at all International Conferences ILUMINAT 2001-2009*
10.50 - 11.10	Professor **Cornel BIANCHI** President of the CIE National Committee of Romania Modern structures of using natural light for natural-electric integrated, efficient and quality lighting systems
11.10 – 11.30	Professor Ir. **Wout van BOMMEL** Philips Lighting, Eindhoven, The Netherlands Fudan University, Shanghai Past president CIE Board IDA Road lighting in the light of the future
11.30 – 12.00	Coffee break
12.00 – 12.15	**Dr. Grega BIZJAK**[*], **Dr. Matej KOBAV,** University of Ljubljana, Slovenia *President of the CIE National Committee of Slovenia Consumption of Electrical Energy for public lighting in Slovenia
12.15 – 12.35	Dr. **David CARTER**, Reader, University of Liverpool, UK Hybrid lighting systems
12.35 – 12.50	Professor **Cătălin D GĂLĂȚANU,** Ass. Professor **Dorin D. LUCACHE** Technical University “Gh. Asachi” of Iasi, Romania Point of view: quality in lighting education
12.50 – 13.10	Professor **Liisa HALONEN**, Head of the Lighting Laboratory Dr. **Eino TETRI** Helsinki University of Technology, Finland Lighting Efficiency and LED Lighting Applications in Industrialized and Developing Countries
13.10 – 13.25	Professor **Virgil MAIER,** Professor **Sorin Gh PAVEL**, Head of the EPS Department Technical University of Cluj-Napoca, Romania Flicker dose in the road lighting
13.25 – 13.45	Dr. **Janos SCHANDA**, Professor emeritus of the University of Pannonia, Hungary **Katalin GOMBOS** Photometry of Solid State Lighting in theory and practice
13.45 – 14.00	**Şerban ȚIGĂNAŞ,** President of the Order of the Romanian Architects, Transylvania Branch **Dana OPINCARIU** Technical University of Cluj-Napoca, Romania What the architects are expecting from the artificial light?
14.00 - 14.15	Professor **Florin POP**, Head of the Lighting Engineering Center Dr. **Dorin BEU**, Reader Technical University of Cluj-Napoca, Romania Ten years of sustainable lighting in Transylvania
14.15 – 14.20	**Award of the Best Paper of Ph.D. students**

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