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INGINERIA ILUMINATULUI - Lighting Engineering journal has a scientific presentation and content, targeted to the continuing education in the lighting field, without any insertion of the commercial advertisings inside of its pages. It has a half-yearly appearance.

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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Intelligent Energy Europe

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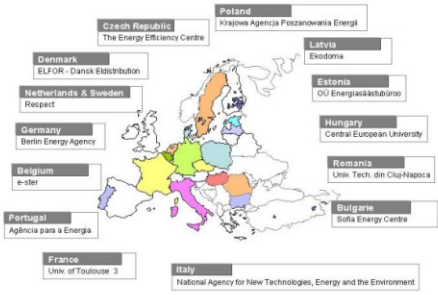
EnERLIn Programme - European Efficient Residential Lighting Initiative

by promoting Compact Fluorescent Lamps in households

Grant EIE/05/176/SI2.419666 (2006-2008)
coordinator Professor Georges ZISSIS, University Paul Sabatier, Toulouse, France
http://www.enerlin.enea.it/



EnERLIn Programme Objectives

Substantial increase of household lighting efficiency in some EU countries

To promote cheap Compact Fluorescent Lamps offer to answer various needs of shapes, dimensions, color rendering and electrical sockets

To support CFLs luminaires design with aesthetic trend through specialized shops

To make and implement a promotional campaign for Compact Fluorescent Lamps and adequate luminaires, according to quality request of European CFL Quality Charter

Luminaires dedicated to CFLs

Different shapes of CFLs

Compact Fluorescent Lamps features

Reduced energy consumption by 80% for the same luminous flux faced to incandescent lamps
Lamp life more than 8 times longer compared to incandescent lamps
Average lamp life of 5 years by using 3.3 hours/ day
Lamp base type E14, E27 or B22
Multiple applications due to the broad range of available lamps
Color temperature range of 2700, 3000, 3500, 4000 and 6000 K - warm white, neutral white and daylight white
Power range from 6 W to 30 W equivalent of incandescent lamps from 25 W to 150 W
A and B energy classes according to the European label systems for household appliances

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LIGHTING AND ENERGY, A SUBJECT ALWAYS CURRENT

Dr. Florin POP, Professor

This issue is based on the papers presented at the international conferences on lighting ILUMINAT 2007 Cluj-Napoca and the 4th BalkanLight Conference on Lighting – Ljubljana and a research contribution. It is the third issue edited under the frame of the EnERLIn IEE program.

The work of **D BEU** and **F POP** analyses the energy efficiency of residential buildings electrical lighting installations in European Union countries. The Lighting Engineering Center of the Technical University of Cluj-Napoca, Romania is involved in two programs for promoting the lighting energy efficiency and saving measures in residential buildings: an European EIE – SAVE EnERLIn and a Romanian CEEX CREFEN. The EnERLIn and CREFEN questionnaire campaign were promoted in several steps, starting with November 2005 till May 2008, concerning the usage degree of GSL and CFLs in households in Western Romania. Finally, both campaigns - CREFEN (November 2005) and EnERLIN (November 2006 - May 2008) denote on average 2.82 CFLs per household. Guidelines for design of future residential energy efficient lighting systems are suggested.

M CHINDRIŞ, A CSIKER and **Anca MIRON** have created an original software tool that calculates the power losses in public lighting networks. The paper presents it by describing its working methodology and the mathematical relationships implemented to obtain power losses. The assessment of power losses is useful in the stage of design and exploitation of the lighting networks. An analysis of a real public lighting network from Cluj-Napoca is also presented. The replacement of the existing HPM lamps of 250 W with HPS lamps of 150 W decreased the supplied power and the total power losses, but produced an increase of the additional power losses. These results can be explained by the harmonic spectrum of the lamps: the HPS lamp introduces more harmonics than the HPM lamp.

S FASSBINDER paper analyses the improvement of the fluorescent lighting by optimizing the selection of specific ballasts for specific lamps. As far as the ranges of small and medium-sized lamps are concerned, these often provide more than one option of combining specific lamps with specific magnetic ballasts. There are three different approaches, one of which or eventually also a combination of which may lead to such effect: different lamps on the same ballast, a different lamp on a different ballasts, and more than one lamp on one ballast. It has become obvious that the difference between the poorest and the optimal combination of lamps with magnetic ballasts covers a much wider range than the transition from magnetic to electronic ballasts. Electric losses may range as high as 50% and as low as 14% of the measured total luminaire or systems power. It is therefore important to select the right combination of a lamp and ballast, since in a variety of cases different lamps can be operated with the same ballast and vice versa. The last conclusion is that, when considering to pay a price premium for electronic ballasts in order to improve energy efficiency, it remains to also consider that, depending on the assumptions you make, it takes between 1000 and 10,000 hours of operation to save 1 Euro of electricity costs.

W KIM, **HT AHN, KH MOON, JT KIM** propose a practical method of selecting glare source in a window having non-uniform luminance. Experiments were conducted using a model window - a luminous body divided into two parts. Each part has the same size but different luminance. The relationship between the degree of discomfort glare and the size of the window was investigated. The result shows that the part with lower luminance is not considered as a glare source when the part has luminance less than 49% of the luminance of the higher luminance part.

Corina MARTINEAC, S ŞTEFĂNESCU, M PALCU, **M HOPÎRTEAN** paper presents the types of audit for lighting systems, pointing out their main characteristics. The steps that auditors have to take are concisely presented, together with the lighting audit forms. Ten lecture rooms of the Technical University of Cluj-Napoca were analysed, and their lighting systems were redesigned after the audit has been completed. The benefits of new lighting system consist in a higher level of illuminances, according to current standards, not in energy savings. Neither dimming, nor switching methods are recommended for the spaces, due to the specific educational programs performed in the lecture rooms.

View is one of the architectural environmental elements affecting human living. The right of view is one of the most important factors in providing residents with psychological comfort and stability in residential environment. **KH MOON, HT AHN, W KIM, JT KIM** paper aims to propose an evaluation algorithm using 3D simulation program. For this, evaluation of the right of view was made by using the case of J Apartment Housing and validation was verified by comparing the view conditions of actual apartment housing. The view ratio was calculated as a percentage (%) of the area not obstructed by the existing and new buildings to the area viewed out of the window. At this time, the area viewed out of the window of the living room was calculated as the opening area. The results of analysis were organized by household opening area, view ratio (%) before new construction, view ratio (%) after new construction and infringement on view ratio (decreased view ratio) due to new construction. To verify the validation of simulation results, the actual view photograph of the apartment house and the view photograph of the simulated image were compared. An evaluation algorithm of the view night using graphic programs was presented and the results are concluded.

C ŞUVĂGĂU continues his very interesting and exhaustive column, “The Lighting in The New World”, with a presentation of the most recent features of the CFLs technology, the CFL market reality and the environmental concerns related to the shift out of the incandescent lamps until 2020. The presentation concludes that, nevertheless, as the world does not stay still, LEDs are developing faster and put a serious treat to the CFL market. However, since LEDs are utterly expensive and they propose a different lighting paradigm (with solid state luminaires rather than replaceable lamps), CFLs could still enjoy a long and happy life.

LIGHTING ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS

Dorin BEU, Florin POP
Lighting Engineering Center, Technical University of Cluj-Napoca, ROMANIA

Paper analyses the energy efficiency of residential buildings electrical lighting installations in European Union countries. The residential sector represents an important potential for reducing the energy consumption, focused on lighting and domestic appliances. In the last years there is an increasing debate about incandescent lamps shift-out and a new CFL charter, related with the residential buildings sector which is the most difficult to regulate or where energy efficient lighting measures face problems in dissemination. The Lighting Engineering Center of the Technical University of Cluj-Napoca, Romania is involved in two programs for promoting the lighting energy efficiency and saving measures in residential buildings: EnERLIn - European efficient residential lighting initiative, an EIE - SAVE program to promote the compact fluorescent lamps in the residential area, and CREFEN - Integrated software system for energy efficiency and saving in residential sector, a Romanian CEEX program.

1. INTRODUCTION

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

Ligth Fair Las Vegas 2006 - [11] - presented the big news in CFLs - the proliferation of a new standard base for CFL fixtures that allows bulbs and fixtures to be interchanged freely. This overcomes a major obstacle for widespread use of CFLs (if you buy a 26 W fixture, you must use a 26 W CFL). To solve the problem, Energy Star worked with manufacturers to develop the GU24 standard. Consumers who purchase fixtures that use GU24 components will be able to change out lamps/ballasts of varying wattage and lumen output to meet their specific lighting needs, making the switch just as easy as it’s been to screw in a 60 W incandescent light bulb to replace a 75 W bulb.

2. ENERLIN - EUROPEAN EFFICIENT RESIDENTIAL LIGHTING INITIATIVE, SUPPORTED BY INTELLIGENT ENERGY EUROPE PROGRAMME

The European Climate Change Programme (ECCP) identified residential lighting as an important area to CO_2 emission reductions. After a considerable number of promotion and rebate schemes, about 135 million CFLs are used today in European homes. However, only 30% of EU households have at least one CFL, with those households that own them having an average of three or four. The residential lighting market is still dominated by inefficient Incandescent Lamps (GSL – General Service Lamps). The EnERLIn EIE SAVE program proposes to develop and validate robust scenarios for CFL promotional campaigns in European, national and regional levels. The European Union initiated numberless campaigns to promote compact fluorescent lamps with the purpose of increasing the market share of CFLs at 15%. The EnERLIn EIE SAVE program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting, and the ultimate objective of the program is to substantially increase the efficiency of residential lighting in a number of Member States [15].

Objectives of the EnERLIn action.

Improving the energy efficiency is a central theme of energy policy within the European Community, as indicated in the White Paper "An Energy Policy for the European Union", since improved energy efficiency meets the three goals of energy policy, namely security of supply, competitiveness and protection of the environment. Lighting represents an important part of building energy consumption in the EU – around 10% of the total electricity consumption, ranging from 5% (Belgium, Luxemburg) to 15% (Denmark, Netherlands, and also Japan) [6]. Residential sector represents 28% from the global electric lighting energy use [8].

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

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

In his presentation [14], Professor Zissis underlines that the energy saving policies and environmental constraints imposed by European regulations push strongly to develop "green" solutions for lighting. At the present case, CFL seems to be the most valid solution. Several European and national programs are devoted to the promotion of this type of lamps and try to limit the GLS use in households. These campaigns are today very efficient and the number of CFL sales increases in Europe rapidly. The average observed growth rate concerning CFL numbers is the order of 13.5% per year (in the order of 11.5% in western and 17% in eastern countries). It should notice that the annual growth rate of the global lighting industry is in the order of 0.8%.

EnERLIn consortium. 14 partners from 14 countries constitute the proposed consortium, covering a large part of the Europe form north to south and from east to west.

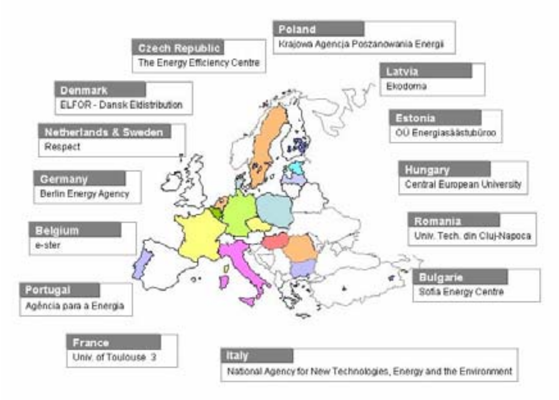

Figure 1 The EnERLIn consortium map. [15]

This is an important issue; because, concerning lighting the reaction of the individual customers is quite different form a country to the other (north countries prefer low colour temperatures lamps, hot ambiance, and south countries are more sensitive to high colour temperatures, cold ambiance). The consortium includes western countries with high GDPs compared to eastern countries that they just integrated EU (Poland, Hungary, Czech Rep., Latvia and Estonia), and the newest EU countries (Bulgaria and Romania). The ENERLIN consortium is strongly cross-disciplinary including National or Regional Energy Agencies (ADENE, KAPE, ENEA, SEC, SEVEn, BE), one ESCO in Belgium, academic institutions (France, Hungary and

Romania), a values-based consultancy focussing on sustainability (Respect) as well as independent consulting SMEs (Ekodoma, Energy Saving Bureau). Each partner has solid experience with EU projects (especially from DG TREN), and strong links with international organisms like CIE and projects like ELI, other European networks (COST-529) and programs (GreenLight). Some partners are quite influential for policy-making bodies in both national (regional) and European levels.

3. CREFEN – INTEGRATED SOFTWARE SYSTEM FOR ENERGY EFFICIENCY AND SAVING IN RESIDENTIAL SECTOR

The **CREFEN project** aims: - to create an integrated software system-tool focused on the applications concerning the electric energy efficient use and saving in residential sector in Romania; - to develop the necessary databases of equipment and endowments from residential sector, using the market surveys and questionnaires; - to develop an advanced modelling and simulation software system-tool of electric energy consumption in residential sector and of economical effects; - to implement an application with databases, an interactive educational application and electronic book related to the energy efficiency use in order to influence the consumers' options in selecting energy efficient appliances for environmental protection [1].

The Romanian National Strategy in the energy efficiency field - 2004 - underlines that the residential sector has a primary energy saving potential at 3.6 millions tones equivalent petrol through 6.8 million tones of the total final consumers; it means more than 50%. This potential can be capitalized by the rehabilitation of the buildings heating insulation, the improvement of the heating and lighting systems and of the electric domestic appliances. The project is connected with energy efficient use according to EU directives from one side and with the implementation of database applications using web-based technologies for assisting and influencing the consumers decision in selecting the domestic and lighting appliances from the other side, that leading to sustainable environment management. The last aim of the project is for environmental protection by reducing the CO_2 emissions.

The software application architecture will be a modular one, with the possibility of its extension with new functionalities, without perturbing the other components or requiring the reorganization of the system data.

4. ANALYSIS OF ELECTRIC LIGHTING ENERGY CONSUMPTION IN THE RESIDENTIAL SECTOR IN ROMANIA

The statistic data [16] for the period 2000 - 2004 allow us to determine the variation of total household consumption, total number of household consumers, average consumption per household consumer, and of the specific consumption kWh/m^2 per year - Figure 2.

During November 2005 a study has been realized on the CREFEN project using feed-back reply forms concerning the usage degree of GSL and CFLs in households in Western Romania. We received 295 replies, namely 220 apartments (with 1–4 rooms - living room and bedrooms) and 75 houses (with 2–more than 7 rooms - living room and bedrooms). The light source equipment is presented in Table 1, and the average installed power - in Figure 3. The specific data referring to the Lamps usage were collected only on the UTC-N questionnaires for the use of received information under the frame of the IEE program EnERLIn, as an explanatory study.

The analysis of the presented data allows us to estimate a few characteristics of electric energy consumption of households. The annual electric lighting household consumption in Romania in 2004 was about 6.83 kWh/m^2/year (based on the average consumption of 255.3 kWh/ household/year and average household surface of 37.39 m^2/ household and the average contribution of the consumption on the lighting circuits - 25% according to the study [3]).

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

Household		GSL		CFL		Installed power
Type	No.	Units	Average	Units	Average	kW
Apartment	220	2624	11,98	367	1,67	0,770
Single-family house	75	1088	14,51	196	2,61	1,028
Total	295	3712	12,58	563	1,91	0,835

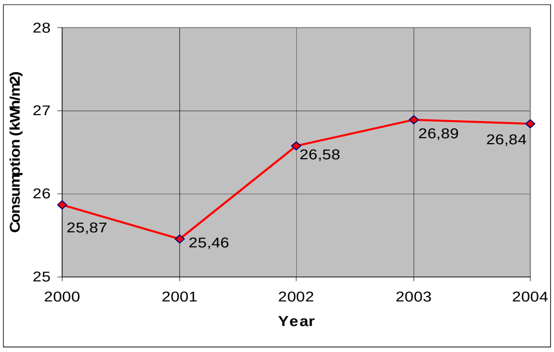

Figure 2 Household consumption per m2 lighting - [9].

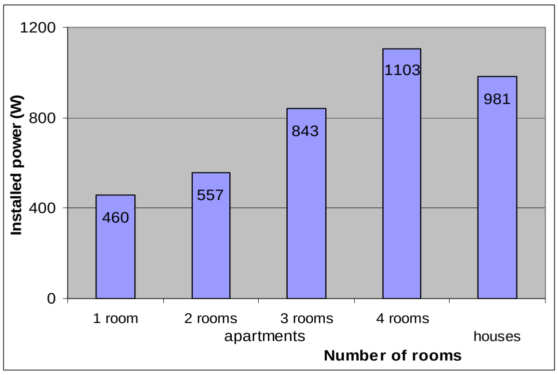

Figure 3 Average installed power in residential in Romania - [9, 15].

The EnERLIn questionnaire campaign was promoted by two subcontractors of the project and the local Electrica distribution company in seven steps, starting with November 2006 till May 2008. There were 545 answers (it means households) and 1804 CFLs used, so the average number of the CFLs is 3.31 units per household. Finnaly, both campaigns - CREFEN (November 2005) and EnERLIN (November 2006 - May 2008) denote on average **2.82 CFLs per household**.

The CFL distribution power is presented in Figure 4 - 545 households.

Newly updated CFL sales figures for Denmark show the CFL distribution power on 2000 Danish households - Figure 5. There are on average 9 incandescent lamps per household, **6 CFL**, and 8 halogen lamps. 16% of Danish households still do not own a CFL. [12]. In Bulgaria, there are on average 0,6 CFLs per households [12].

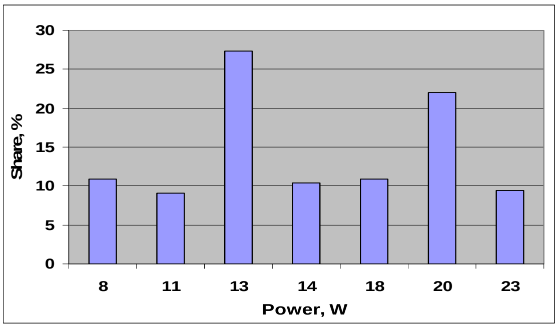

Figure 4 CFL distribution power in Romania - 545 households, 2008.

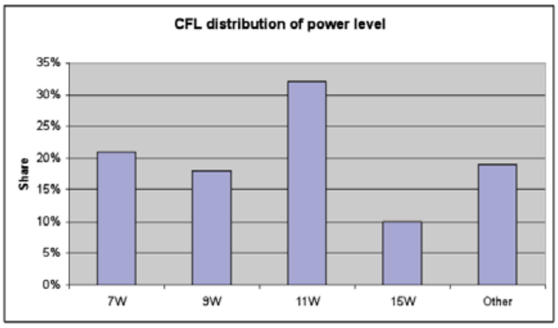

Figure 5 CFL distribution power in Denmark - 2000 households - [12].

A CREFEN Questionnaire Summer 2006 campaign was realized in order to acquire information as ownership rate for each appliance, rated power, average operation period and others (efficiency, resources consumption). The households' composition was desegregated by urban multi-apartment block, single urban dwelling and single rural dwelling. The households' distribution was made according different criteria as: geographic site, rural or urban environment, family income, dwelling size. A total of 204 questionnaires were obtained from a large geographical area. The first obtained data regards the attitude of the questioned people to the energy efficient domestic appliances topic - more than 70% agree that the decision to buy an appliance should be based on energy efficiency class as well. The consumption in the household utilities is presented in the Figure 6. The motivation of the CFLs use is presented in Figure 7.

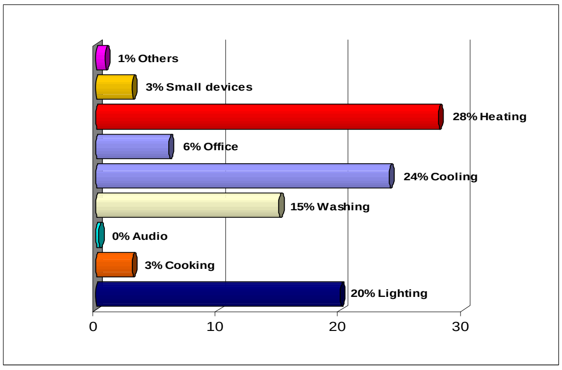

Figure 6 Consumption of household appliances [1].

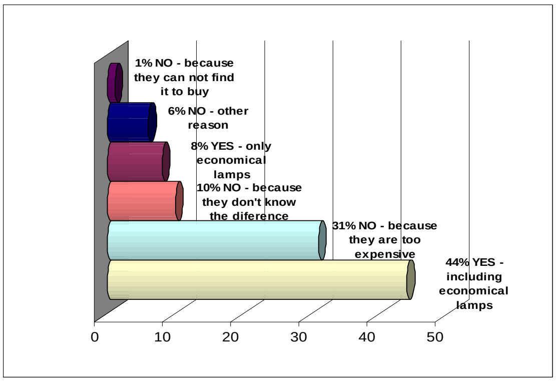

Figure 7 Motivation of the CFLs use [1].

In further works, after receiving and processing the data, the reference status of the residential electricity consumption at the level of the year 2006 will be obtained. The residential electricity demand will be estimated using the MAED model elaborated by the IEA, following development scenarios on medium and long terms.

5. NEW CFL QUALITY CHARTER

This year the European Commission, through Joint Research Centre, is preparing a new European Compact Fluorescent Lamps Quality Charter. In the introduction is mentioned that "total domestic lighting consumes about 86 TWh in the Union and it is predicted to raise to 102 TWh by 2020. Compact fluorescent light bulbs (CFLs) use at least 60% less electricity than the traditional incandescent lamps while lasting ten to twelve times as long and can therefore deliver substantial savings in terms of both electricity and money." The idea of this quality charter is to promote CFL for the remaining 95% of the residential lamp market, but with minimum quality criteria in order to increase consumer confidence. The mains modifications are related to stabilised light output (time to 80% of stabilised light output, after switch-on from cold, at normal room temperature, shall be less than 60 seconds and 30% of stabilised light output after switch-on from cold, at normal room temperature, shall be less than 2 seconds) and comparison CFL/GLS (instead of previous 1:5 ratio, a new 1:4 is indicated.

6. INCANDESCENT LAMPS SHIFT-OUT

EU has proposed a ban on incandescent light bulbs, planned to come into effect in the near future, but this will not affect existing incandescent bulbs, only the production of new bulbs. This proposal has to be approved by all member states or the European Parliament. Italy will ban the sale of incandescent light bulbs as of 2010. Germany's Environment Minister has urged the EU to ban inefficient light bulbs in the EU in the fight against global warming. The EU could reduce carbon dioxide emissions by 25 million tonnes a year if energy saving light bulbs were used in both the domestic and services sectors. Belgium's Minister of the Environment is intent to ban incandescent light bulbs, and thinks the ban on incandescent light bulbs should be included in the list of measures under the Kyoto Protocol. In Ireland, the government proposes to ban traditional incandescent light bulbs in 2009. On the 27 September 2007, the government in the UK announced plans to phase out the sale of incandescent light bulbs by 2011. Under the plan, retailers will voluntarily decline to stock 150 W bulbs from January 2008, 100 W bulbs from January 2009, 40 W bulbs in 2010, and all remaining bulbs by 2011. These plans are voluntarily, however they have had wide support from retailers and consumers. Though the initiative has been criticised by environmental groups such as Greenpeace, and other political parties, who believe mandatory measures should be introduced.

Figure 8 Luminaires with CFLs for residential use

7. LESSONS LEARNT DURING THE FIRST TWO YEARS OPERATION OF EnERLIn PROGRAMME

Professor Zissis considers that during the past 24 months since the starting of the project, the main lessons learned by the consortium are the following [13]:

End-user is very regarding on CFL-Quality. Low quality devices "pollute" the market and seriously impede the increase of market penetration of that energy efficient technology. A systematic CFL-quality control is imposed in EU level following a well-defined unique testing protocol and associated with readable and compulsory labelling.

There is a significant lack of knowledge and data on the penetration and the trends in use of various lighting technologies in households. This is especially true in Eastern European countries, therefore it is difficult to clearly articulate what we would like to achieve with a campaign and whom exactly we could target in order to increase efficient light sources penetration.

An important aspect which was raise during discussion with end-users is the lack of CFLs dedicated luminaires. That is why we had asked a local architects and designers board to choose a 10 generic types of luminaires as good example - Figure 8. These luminaires range from classic shapes to trend setting and they are a solution to crystal type chandeliers which is widespread.

The involvement of many different actors and coordinating with the government authorities and ministries level needs an important investment on time than expected but it is necessary. The politic attention on Climate Change have created activities in many levels in the society which have engaged the EnERLIn people in many discussions to coordinate action.

Energy efficient lighting has become a more and more relevant topic in all sectors: private consumers, public authorities, and in enterprises. Increasing costs for energy and maintenance, environmental debates, and several EU Directives have especially increased the demand for energy saving solutions in municipalities. Also in the sector of private end-consumers, the awareness for environmental integrity and high-energy prices have lead to a rethinking in the use of energy saving lighting. The potential for the implementation of environmental friendly and cost saving lighting measurements is still very high. Initiatives such as EnERLIn play a major part in promoting such technologies and help to overcome barriers. The high number of participants in the workshop series and the high demand for advisory on the one hand and the still low number of good practice examples proves this.

8. CONCLUSIONS

The estimated total electric energy consumption, 255.3 kWh/household/year, and the total lighting energy consumption in the Romanian residential sector, 25% of the total household electric energy consumption, are values that fit in the references limits. The average number of the CFLs is 2.82 units per household. One CFL mounted in each household of Romania would lead to a decrease of the household electric energy consumption of around 45,246 MWh/year, saving 2.5 kTones CO_2 emissions [9]. The predictable economic impact could be established by the adoption of policies towards an electric energy consumption reduction, both locally and nationally. It is essential to increase the awareness of the energy efficiency both by users and by electric energy providers, in order to reduce the consumption peaks that are specifically due to lighting.

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Intelligent Energy Europe

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COMPUTATION OF POWER LOSSES IN PUBLIC LIGHTING NETWORKS

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Technical University of Cluj-Napoca

In our present society, public lighting has become a necessity. The modern public lighting networks include mostly high-pressure mercury and sodium lamps, operating based on the arc-discharging phenomenon. Due to the non-linear characteristic of the lamps and to the fact that the lamps are unequal distributed on the three phases of the 3 phase-4 wires lighting network, the latter is functioning in a unbalanced and non-sinusoidal regime.

The existence of this non-sinusoidal and unbalanced regime leads to many negative effects; from them, the growth of power losses in the phase conductors and the neutral conductor respectively, represents the interest issue of this paper. The assessment of power losses is very important in the stage of design and exploitation of the lighting networks.

Based on the mathematical relationships and theoretical results presented to the last editions of this conference [2, 3], the authors have created an original software tool that calculates the power losses in public lighting networks.

The paper presents this software tool by describing its working methodology and the mathematical relationships implemented to obtain power losses. The product is very friendly user and assists people with reduced computer knowledge during operation. An analysis of a real public lighting network from Cluj-Napoca is also presented.

1. INTRODUCTION

Public lighting has become an ordinary aspect of our modern society. Unfortunately, due to the existence of discharge lighting sources, present low voltage three-phase 4 wires public lighting networks have problems from both power quality and neutral current points of view; practically, they are working in a non-sinusoidal and unbalanced regime.

The effects of this operation state decrease the energy transfer efficiency as a consequence of additional power losses in lines and transformers. Considering the necessity of accurate knowledge of power losses in public lighting networks design and operation stages, a dedicated software tool was created. This tool calculates power losses in public lighting networks that operate in a non-sinusoidal and unbalanced regime.

Further on, the paper presents aspects about modern public lighting networks, the software tool interface, working methodology and analytic support; finally, the analysis of a real public lighting network is presented.

2. PUBLIC LIGHTING NETWORKS FUNCTIONING IN A NON-SINUSOIDAL AND UNBALANCED REGIME

Modern public lighting networks include discharge lamps, like high-pressure mercury/sodium lamps, which are single-phase non-linear loads. It is known that in the case of three phase four wire distribution networks containing non-linear loads, an important effect of the harmonic pollution consists of a supplementary neutral current. For balanced systems, the neutral current is the summation of the 3k order harmonic currents, that is:

$$i_n = 3\sum_{k=1}^{\infty} I_{3k} \cdot \sin(3 \cdot k \cdot \omega \cdot t + \beta_k) \qquad (1)$$

with the RMS value

$$I_n = 3\sqrt{\sum_{k=1}^{\infty} I_{3k}^2} \qquad (2)$$

where I_{3k} is the RMS value of the 3k harmonic current.

In order to establish the non-sinusoidal state imposed by the discharge lamps, measurements have been performed using a FLUKE 43 Power Quality device. Common luminaries of different wattages equipped with high-pressure mercury/sodium lamps and ballast were studied.

The next figures illustrate the line current harmonic spectrum for the high intensity discharge lamps LPN250, LPN150 and LVF250, and the voltage and current waveforms for LPN150 respectively.

In most cases, in a public lighting network, lamps are unequally distributed between the three phases, and thus the electrical distribution system becomes unbalanced. In this situation, through each line conductor currents with different RMS values are flowing, and the neutral current is the summation of the 3k order harmonic currents plus the zero phase sequence of the 3k+1, 3k-1 harmonics, and fundamental current respectively.

2.1. Calculus of power losses

An alarming consequence of the non-sinusoidal unbalanced existing regime is the increase of power losses in the active conductors and especially neutral conductor.

Considering a public lighting network that illuminates a roadway, Figure 5, power losses can be obtained by using the relationship (3).

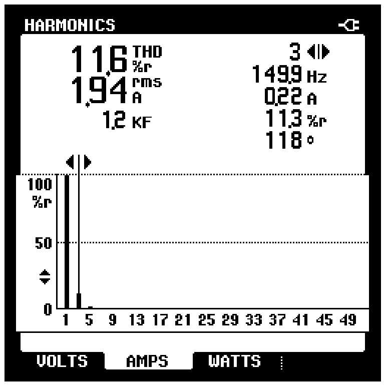


Figure 1 Harmonic current spectrum –LVF250

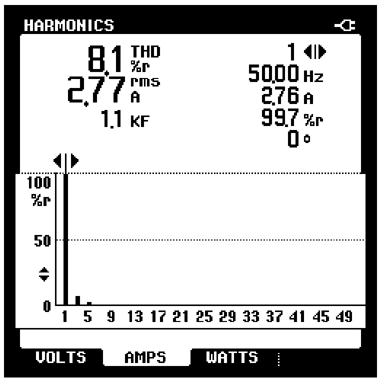
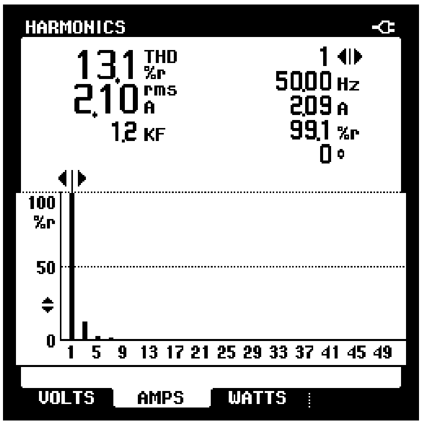


Figure 2 Harmonic current spectrum – LPN250



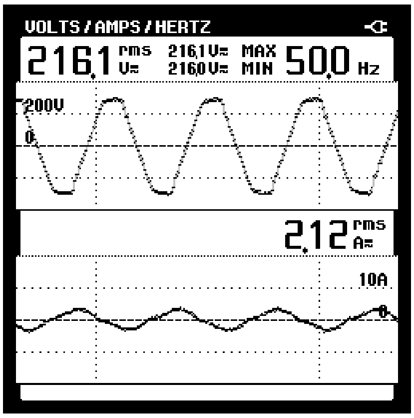


Figure 3 Harmonic current spectrum – LPN150 **Figure 4** Voltage and current waveforms – *LPN150*

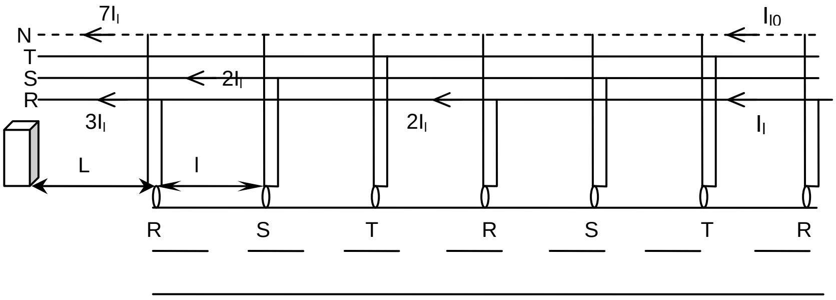


Figure 5 Public lighting network – electrical connection and currents flow

$$\Delta P_{Total} = \Delta P_R + \Delta P_S + \Delta P_T + \Delta P_N \ [W];$$
$$\Delta P_X = \sum r \cdot l_y \cdot \sum_{k=1}^{N} I_k^2 \ [W], \quad X = R,S,T,N; \tag{3}$$

where ΔP_{Total} are total power losses;

ΔP_X – power losses in an active (neutral) conductor;

I_k – k order harmonic current;

r – conductor resistance per unit length;

l_y – segment length of the phase(neutral) conductor for which the power losses is calculated.

Additional power losses in the unbalance non-sinusoidal operation can be calculated by using relationship (4), where the total power losses are reported to the power losses calculated for a sinusoidal balanced operation.

$$\Delta p = \frac{\Delta P_{Total} - \Delta P_{\sin}}{\Delta P_{\sin}} \cdot 100 \ [\%] \tag{4}$$

where Δp represents the additional power losses;

ΔP_{sin} - the power losses in sinusoidal balanced regime.

The calculus of ΔP_{sin} is made considering the following aspects:

- the network supplies linear loads having the same total power as the real case;
- the distribution of the lamps between phases is made as presented in reference [1].

3. SOFTWARE TOOL

The software tool calculates active power losses in the electric conductors of a public lighting network, considering the unbalanced non-sinusoidal state caused by the discharge lamps. The informatics program is composed of two parts: a friendly GUI (graphic user interface) and the operating modules, further described on this chapter. For developing an easy to use software tool, the Borland C++ Builder visual development environment was used.

3.1. Graphic User Interface

The graphic user interface represents the part of the software with which the user comes in contact, so that a simple and easy to understand GUI was built up. Through it, user can introduce the input data and visualize the obtained results. GUI consists of one main window, presented in figure 6, and several auxiliary windows. The secondary windows were made for different purposes:
- to introduce supplementary input data;
- to show lamps database;
- to assist the user for different operations.

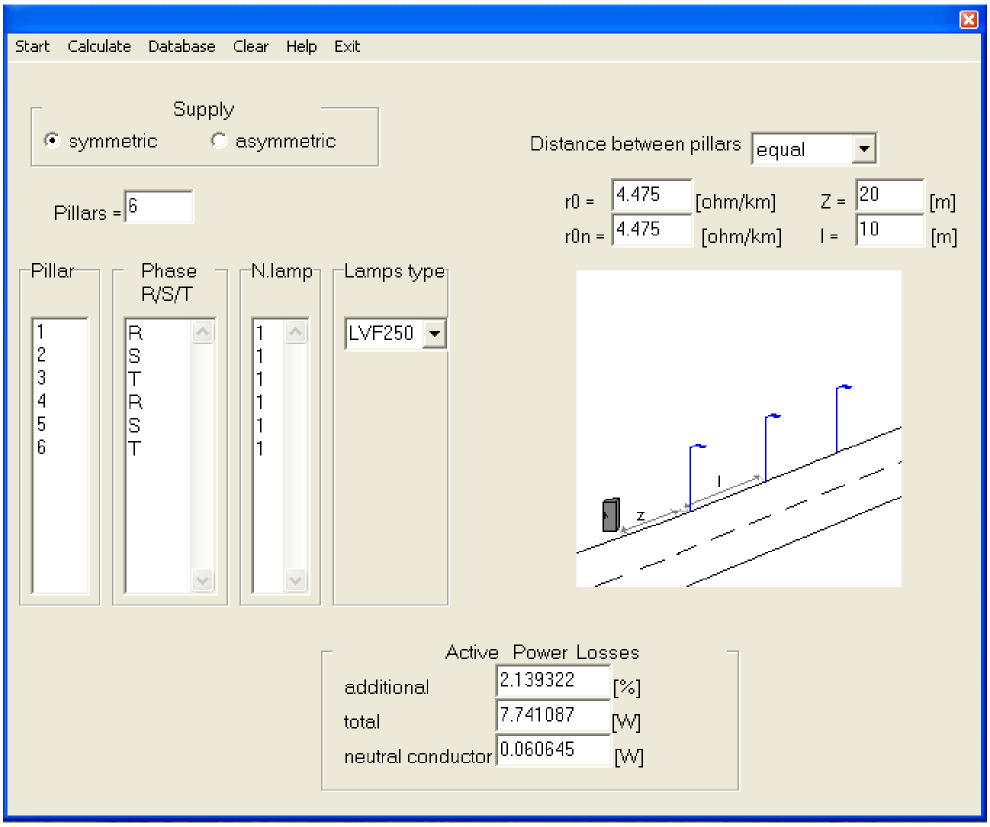


Figure 6 Graphic User Interface – main window

3.2. Operating modules

The operating modules represent the source code of the software written in C++ and user has not access to them. These modules have different functions:

- to add new lamps in the database;
- to adjust input data depending on the supply and on the type of the electrical public lighting network;
- to calculate power losses.

Considering the main issue of the present paper, the operating module that calculates power losses has the greatest importance, and as a consequence this module will be presented further on.

Figure 7 shows the working diagram of the power losses module; as it is described in this picture, the calculus begins by pressing "Calculate" field of the main menu bar. There are some steps that are performed:

- Input data are read;
- The phase coupling is verified;
- For each phase the following data are calculated:
  - the RMS value of the current,
  - the length of the conductor,
  - the active power losses;
- RMS value of the neutral current and corresponding power losses are calculated;
- Total power losses and additional power losses are determined;
- Results are put on desktop for visualization.

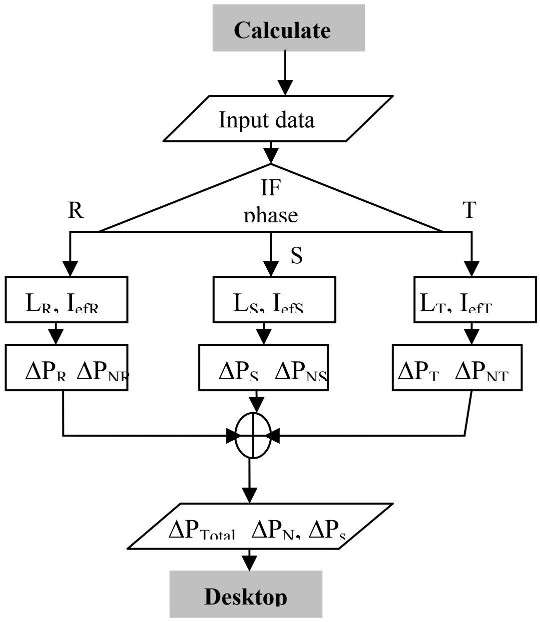


Figure 7 Working diagram of the PLM

4. ANALYSIS OF A REAL PUBLIC LIGHTING NETWORK IN CLUJ-NAPOCA

To test the created software tool, a real electrical public lighting network was studied. In the last years, during a campaign of modernization, a main task was to improve the photometric performances of public lighting systems; simultaneously, an other goal was to grow the efficiency of the electric network, in order to decrease the power consummation, i.e. voltage and energy losses. Accordingly, the existing luminaries PVB-7 B 1x250 W and PVO-1x250 W, have been replaced by new ones M2A – TC 150 W, more efficient. For supplying the luminaries, the following types of conductors were used:

- AFYI 3x35+35 mm^2 between pillars;
  $r_0 = 0{,}871$ [Ω/km];

- ACYAbY 3x50+25 mm^2 from the plugboard to the first pillar; r_0= *1,116 [Ω/km]*.

The analyzed public lighting network contains a number of 40 pillars and has the following characteristics:

- distance between the first pillar and the plug board *z = 20 m*;
- distance between the pillars *l = 30 m*;
- on every pillar there is a single luminary and each luminary has one lamp.

Harmonic spectrum of M2A – TC 150 W lamp is presented in table 2.

Tabel 2 Currents harmonic spectrum of M2A – TC 150 lamp

Harmonic order k=1,N	1	3	5	7
RMS value of the harmonic current I_k [A]	1.82	0.27	0.06	0.04
Phase angle of the harmonic current φ_k [degrees]	0˚	132˚	115˚	152˚

Before the computation, the following characteristics were selected on the main window:

- the supply - “symmetric”;
- the distance between – “equal”;

After the calculus is made, the obtained results are presented in Table 3 where ΔP_{Total} [W] denotes total power losses, ΔP_s [%] - additional power losses, ΔP_{sin} [W] – ideal power losses (balanced loading and linear loads), and ΔP_N [W] – power losses in the neutral conductor.

Tabel 3 Results comparison

Lamp / Power losses	PVB-7 B 1x250 W	M2A – TC 150 W
ΔP_{Total} [W]	795.49	765.49
ΔP_{sin} [W]	658.41	579.47
ΔP_s [%]	20.82	28.08
ΔP_N [W]	75.51	125.21

5. CONCLUSIONS

Electrical public lighting networks practically operate in a non-sinusoidal unbalanced state that causes additional power losses in the active conductors and neutral conductor. As the knowledge of power losses has a great importance in the stage of design and exploitation of the lighting network, the necessity of power losses computation considering the real non-sinusoidal unbalanced existing regime became imperative. Considering these aspects, a software tool that calculates power losses in electric networks supplying public lighting luminaries was designed.

The proposed software was used to analyze a real electric public lighting network in Cluj-Napoca, where the existing PVB-7 B 1x250 W (high pressure mercury lamps) were replaced by new ones that consume less power: M2A – TC 150 W (high pressure sodium lamp). From the results, it can be seen that this process decreased the supplied power and the total power losses but produces an increase of the additional power losses. These results can be explained considering the harmonic spectrum of the lamps: the high-pressure sodium lamp introduces more harmonics than the high-pressure mercury lamp.

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SAVING ENERGY AND REDUCING REACTIVE POWER THROUGH OPTIMAL COMBINATION OF FLUORESCENT LAMPS AND MAGNETIC BALLASTS

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In the course of increasing importance of energy efficiency it is vital also to consider the energy consumption of lighting. In general, one step to improve lighting efficiency is to shift from magnetic to electronic ballasts, or to compact fluorescent lamps (CFLs), respectively, as far as smaller lamps are concerned. But the improvement is limited, the cost implication is major, and disappointment may arise from poor reliability and EMC problems.
More progress at less cost premium is possible by shifting from the poorest magnetic ballasts (which should no longer be – but still are – on sale in some European countries) to the models with the best available energy efficiency index (EEI).
However, as far as the ranges of small and medium-sized lamps are concerned, these often provide more than one option of combining a specific lamp with a specific magnetic ballasts. Many ballasts are rated for several different lamp wattages or for different lamp types of equal wattages. Some ballasts are specified to feed either one lamp or two lamps simultaneously. Optimizing the selection bears a greater savings potential than either of the above mentioned steps – and may even reduce the first cost investment!

1 Minimizing the need for reactive power compensation

The lamp voltage across smaller, i. e. shorter fluorescent lamps of the same type family is lower than with the longer types of the same series. Thereby a larger part of the voltage drops across the ballast, and this voltage drop is greatly – in the ideal case would be wholly – inductive. So on the one hand a luminaire with a smaller lamp has a lower active power intake, but on the other hand it has a higher reactive power dissipation. Commonly, both of these two effects lead to a substantially lower power factor for the lower lamp power ratings than for the higher. So, in relative terms, the compensation investment increases inappropriately when selecting small lamp units. Vice versa, it can be reduced to a fraction by selecting the greatest lamp rating that can be connected to one ballast. There are three different approaches, one of which or eventually also a combination of which may lead to such effect:

1.1 Different lamps on the same ballast

Such effect can be observed very clearly on the TC-S lamps with 5 W, 7 W, 9 W and 11 W power ratings, since all of these four models use the same ballast (Figure 1 or Figure 2): As the lamp power rating connected to one and the same ballast increases, the amplitude of reactive power which remains to be compensated decreases (Figure 5).

1.2 A different lamp on a different ballasts

It also remains to be considered whether a different type of lamp with the same power rating can be found but which has a higher lamp voltage. A higher lamp voltage would mean a lower voltage drop across the ballast and thereby a lower reactive power rating of the ballast. At the same time the current would be smaller when the lamp voltage is greater and the lamp power rating remains the same, so this would reduce the reactive power requirement a second time. This is the case, for example, when replacing a linear 18 W T8 lamp with an 18 W TC-D lamp (Figure 7 left) along with the required ballast (Figure 7 top right). The effect can be tremendous and may cut the reactive power by nearly 50% (compare third to fourth measurement in Figure 6).

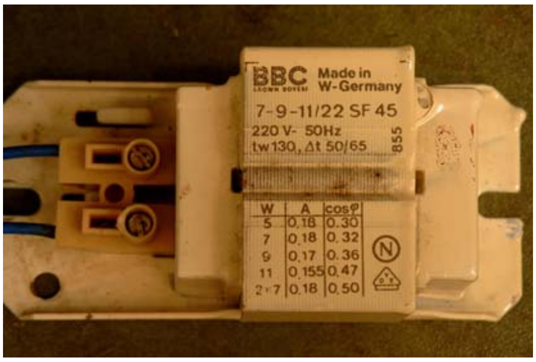

Figure 1 One and the same ballast is designed for four different single lamps and three possible tandem configurations (for reasons of space only one listed here). Current ratings are slightly lower for higher lamp power ratings!

Figure 2 Equivalent ballast as in Figure 1 – later model and different manufacturer. Power factor (λ) ratings are significantly higher for higher lamp power ratings!

1.3 More than one lamp on one ballast

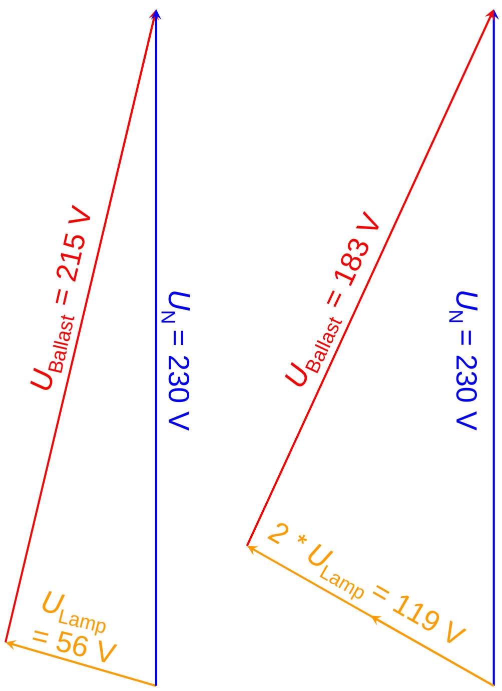

Figure 3 Simplified vector diagram for single and tandem mode operation of a 5 W TC-S lamp – it seems that 2*56 V=119 V in this case but this is because current is slightly lower in tandem mode, which makes lamp voltage greater!

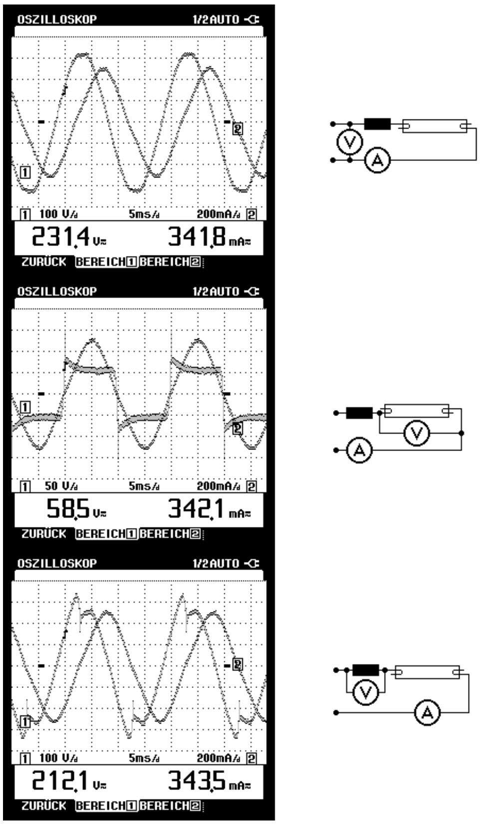

Figure 4 Voltages across a fluorescent lamp and a magnetic ballast

Another option is to operate two lamps on one ballast. Turning back to the TC-S lamps, it remains to be noted that the lamp voltages of the 5 W, 7 W and 9 W models are so low that the common mains voltage of 230 V allows two of these lamps to be operated in series on one ballast. In effect, this doubles the lamp voltage, of course. To be precise, it more than doubles the lamp voltage because of the inverse behaviour of a gas discharge. Since the same ballast is used for this so-called tandem connection as for the single-mode operation, the actual current when operated in tandem lies slightly below the lamp current rating – though not very much, as the inductive voltage drop still prevails and adds orthogonally to the active drop (Figure 3). One of the advantages of this operating mode is that **two** lamps **together** use **less** reactive power than one of them already does in single mode (Figure 5, Figure 6). But it is obvious that this mode does not work on TC-D lamps because their lamp voltages are too high. Rather, one TC-D lamp alone already performs a great deal better than one TC-S lamp alone.

As an aside, it can also be observed in Figure 3 that apparently the right angles, especially in the triangle on the right side, are not really right angles. This is not due to drawing inaccuracy but dates back to the fact that the voltages across ballasts and lamps are highly distorted (Figure 4), while vector diagrams are basically applicable to sinusoidal wave forms only.

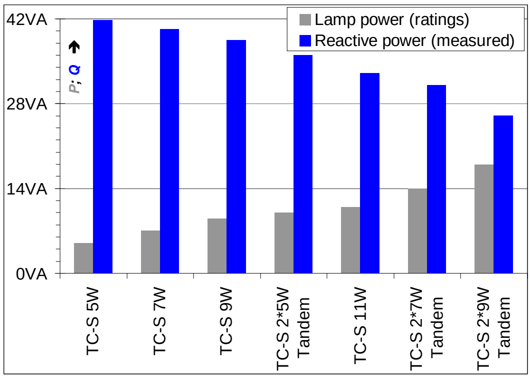

Figure 5 Power factor as the ratio of active power (grey benches) plotted against reactive power (blue benches) for different TC-S lamps from 5 W to 11 W with the same ballast, single and tandem modes

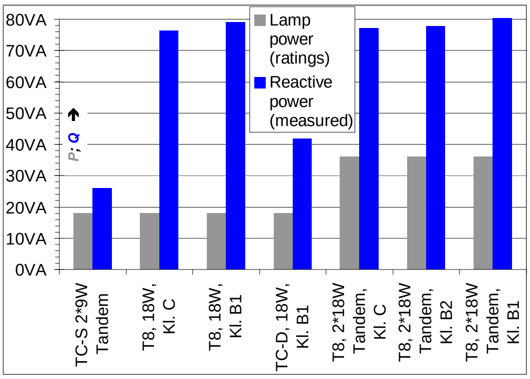

Figure 6 Power factor as the ratio of active power (grey benches) plotted against reactive power (blue benches) for 18 W lamps and different ballasts, single and tandem modes (for comparison, 2*9 W tandem mode also included)

2 Minimizing active power losses in the ballast and maximizing lamp efficiency

Figure 7 TC-D lamp 18 W, energy efficient magnetic ballast and electronic ballast for this (top) and B1 magnetic ballast for a commonplace T8 lamp of equal power rating (bottom)

Advertisements in favour of electronic ballasts occasionally claim that in magnetic ballasts »up to 30%« of the luminaire's total power intake is absorbed as losses.

***Table 1** CELMA values for smaller lamps*

Lamp power rating		Maximum input power of ballast & lamp circuits					
50Hz (magnetic)	HF (electronic)	Class D	Class C	Class B2	Class B1	Class A3	Class A2
5W	4.5W	>14W	14W	12W	10W	8W	7W
7W	6.5W	>16W	16W	14W	12W	10W	9W
9W	8.0W	>18W	18W	16W	14W	12W	11W
11W	11.0W	>20W	20W	18W	16W	14W	14W
18W	16.0W	>28W	28W	26W	24W	21W	19W
36W	32.0W	>45W	45W	43W	41W	38W	36W

First of all, it remains to be noted that a statement like »up to«, very popular though it may be, is at the same time totally inappropriate to make any statement at all, unless simultaneously complemented by indicating the mean and the maximum values. The same applies here: The greatest relative losses occur with the smallest lamps. This can be traced back to a law of nature once called »The Paradox of the Big Machine« [1]. In a 58 W lamp, for instance, it is only 13%. So the indication »up to 30%« tells nothing at all. On the other hand, this is even disexaggerated. For instance, when measuring the power shares on a TC-S lamp rated 5 W and operated with a conventional magnetic ballast, a lamp power magnitude of 5.6 W may be found, along with once again the same magnitude of ballast losses, so in this case you may very well speak of 50% losses.

Although the Ballast Directive 2000/55/EC does not cover lamp wattages smaller than 15W, CELMA [2] did include the small wattage lamps into their EEI classification (an extract is shown in Table 1). This makes it easier to compare and assess different modes of operation. Again, there are three possible approaches for optimisation.

2.1 Different lamps on the same ballast

While the lamp voltage across shorter lamps of the same type family is lower than with the longer types of the same series, the current rating for the longer lamps being operated on the same ballast is a bit lower (Figure 1 and Figure 2). However, the ballast losses are approximately proportional to the square of the current. So if you replace the 5 W lamp in one and the same luminaire with a 7 W lamp, which is not a problem at all if only the greater lamp length can be accommodated, under the bottom line you receive more lamp power at lower power loss.

But this is still not the full story, since the lamp voltages across the TC-S lamps rated 5 W, 7 W and 9 W are so low that the common mains voltage of 230 V allows two of these lamps to be operated in series on one ballast. This more than doubles the lamp voltage (Figure 3). As the same ballast is used for this so-called tandem connection as well as for the single-mode operation, the actual current and thereby the resulting power when operated in tandem lie slightly below the ratings. In order to minimize the deviation, the magnetic ballasts are designed in a way so that in single mode the current and power magnitudes are slightly above the lamp ratings. In total, the effect is that the ballast is always less loaded, the more lamp power rating is connected to it. More lamp load leads to an absolute drop in losses and thus, in relative terms, saves duplicate (Figure 8).

Table 2 Comparison of electrical data and light outputs with small fluorescent lamps

Type (device under test)	Metering conditions	Measurements DIAL								Calculated values				
		U V	P_{tot} W	P_{Ball} W	P_{Lamp} W	I mA	U_{Ball} V	U_{Lamp} V	Φ lm	η_{Lamp} lm/W	η_{tot} lm/W	S_{tot} VA	Q_{tot} Var	P_{Loss}/P_{tot}
CFL Megaman 4W		**207.2**	3.43	---	---	29.7	---	---	159.1	---	**46.39**	6.2	5.1	---
	Rated voltage →	**230.0**	3.86	---	---	30.6	---	---	172.9	---	**44.79**	7.0	5.9	---
		253.1	4.30	---	---	31.5	---	---	183.8	---	**42.75**	8.0	6.7	---
CFL Action Sunlight 11W		**207.1**	9.59	---	---	98.7	---	---	479.6	---	**50.01**	20.4	18.1	---
	Rated voltage →	**230.0**	10.82	---	---	102.6	---	---	504.8	---	**46.66**	23.6	21.0	---
		252.9	12.04	---	---	106.5	---	---	529.0	---	**43.93**	26.9	24.1	---
CFL Osram Dulux EL 11W		**207.4**	10.52	---	---	78.0	---	---	593.3	---	**56.40**	16.2	12.3	---
	Rated voltage →	**230.3**	11.80	---	---	80.1	---	---	657.9	---	**55.75**	18.4	14.2	---
		253.3	13.02	---	---	81.9	---	---	706.4	---	**54.26**	20.7	16.2	---
Osram Dulux S 9W		**207.0**	11.05	3.70	7.40	150.0	190.8	58.5	509.0	68.79	**46.07**	31.1	29.0	33.5%
	Rated voltage →	**230.0**	13.29	5.10	8.20	176.0	215.3	56.4	559.9	68.28	**42.13**	40.5	38.2	38.4%
		253.0	16.47	7.30	9.20	212.0	239.2	53.9	612.6	66.59	**37.20**	53.6	51.0	44.3%
2*Dulux S	Rated voltage →	**230.0**	16.64	3.20	13.50	136.6	182.6	119.2	928.4	68.77	**55.79**	31.4	26.6	19.2%

Simultaneously, the lamp efficiencies improve when the lamps are not operated at full power, and inversely efficiencies drop when lamps are driven into the overload range. This was revealed during a measurement carried out by a well respected and independent lighting institute [3], recording not only the electrical values but along with these the light output (Table 2). In this test the 9 W lamp turned out at the end of the scale, since the 5 W and 7 W lamps had already disqualified themselves to participate at all, based on the results of a pre-test displayed in Figure 8.

2.2 Different lamps on different ballasts – comparison also to electronic CFLs

Albeit, the light output efficiency with a tandem connection of two 9 W lamps on one magnetic ballast – and even an old, less efficient one – turned out equal to that of a high-end CFL and 20% better than a cheap CFL from the DIY supermarket! It remains to be stated here that the operation of a CFL is always an operation with an (integrated) electronic ballast! So much about the better lamp efficiency with electronic ballasts. Compared to the single-mode operation of one 9 W TC-S lamp the 2*9 W tandem configuration turned out 25% more efficient – with the same ballast and same lamp(s), after all! However, the light output is a bit less than double that of the single lamp. This remains to be considered when designing a lighting installation.

2.3 More than one lamp on one ballast – good wherever possible

But the tandem connection is also applicable to T8 lamps with a power rating of 18 W. Although in this case different ballasts are meant to be used for single and tandem configuration, the results are similarly profitable. Here, too, the finding is that the power loss in the class B1 ballast attributable to two lamps is even lower than that in the class B1 ballast for only one lamp (Figure 9).

Now there are some more lamp types with a rating of 18 W available on the market, e. g. the TC-D lamp. It has a much higher lamp voltage and can therefore not be operated in tandem mode, but since the lamp voltage under normal operating conditions is greater, the voltage drop across the ballast is smaller. So the required reactive power rating of the ballast is also selected to be accordingly smaller – and thereby the whole ballast is smaller.But this is not yet all. When the lamp voltage is greater, the lamp current is also smaller and reduces the required reactive power level again. Therefore a magnetic ballast for a TC-D lamp can be built extremely small, also when designed according to EEI class B1 – even smaller than a commensurate electronic ballast (Figure 3)! So especially a luminaire with a TC-D lamp and a high-efficiency magnetic ballast saves space, production costs and energy in one go.

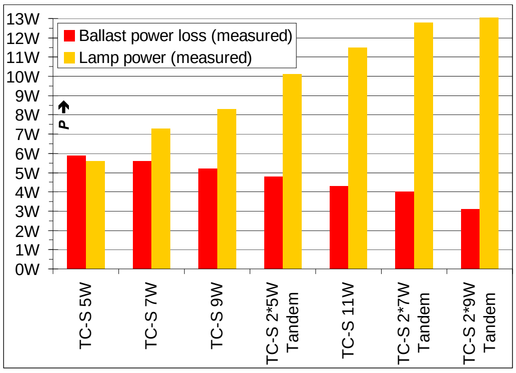

Figure 8 Split of total luminaire power intake for different TC-S lamp configurations with the same ballast

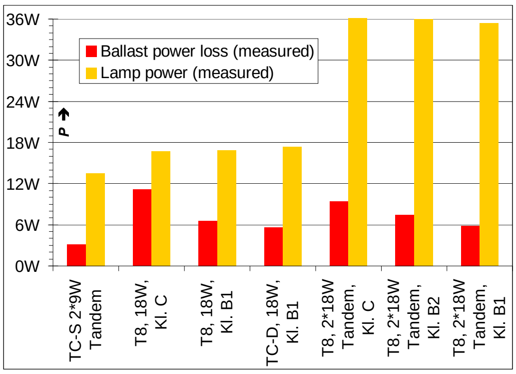

Figure 9 18 W fluorescent lamps in single and tandem mode (for comparison, 2*9 W tandem mode from Figure 8 also included)

2.4 Put them all to the test

The latter finds its confirmation when you add another light output measurement. For this reason the single and tandem operation modes of class B1 magnetic ballasts for 18 W and 2*18 W, respectively, were compared to a single and twin operation mode on an electronic class A2 ballast rated 18 W or 2*18 W, respectively. The results are compiled in 3 blocks of 7 measurements of the light flux *Φ* each, displayed in Table 3:

- one single T8 lamp,
- two T8 lamps in tandem or twin mode, respectively,
- one TC-D lamp,

with the following ballasts and data:

- electronic ballast at the lower voltage tolerance limit 90% (207 V),
- electronic ballast at rated voltage (230 V),
- electronic ballast at the upper voltage tolerance limit 110% (253 V),
- magnetic ballast at the lower voltage tolerance limit 90% (207 V),
- magnetic ballast at rated voltage (230 V),
- magnetic ballast at the upper voltage tolerance limit 110% (253 V)
- magnetic ballast at the voltage magnitude where the light output equals that of the same lamp with electronic ballast at 230 V.

Table 3 Compilation of measuremets on 18 W fluorescent lamps

Type (device under test)	Metering conditions	Measurements U V	P_{tot} W	P_{Ball} W	P_{Lamp} W	I mA	U_{Ball} V	U_{Lamp} V	Φ lm	Calculated values ξ_{Lamp} lm/W	ξ_{tot} lm/W	S_{tot} VA	Q_{tot} Var	P_{Loss}/P_{tot}
18W T8 lamp electronic ballast VS 188314, EEI=A2		**207.0**	19.10			98.4			1382		**72.34**	20.4	7.1	
	Rated voltage →	**230.0**	19.13			90.6			1381		**72.19**	20.8	8.3	
		253.0	19.10			85.0			1383		**72.41**	21.5	9.9	
18W T8 lamp magnetic ballast VS 164572, EEI=B1		**207.0**	20.96	4.70	16.23	304.7	186.6	62.7	1195	73.65	**57.03**	63.1	59.5	22.4%
	Rated voltage →	**230.0**	24.47	6.24	18.21	354.6	211.2	60.6	1320	72.50	**53.95**	81.6	77.8	25.5%
	Φmag=Φelec →	**241.7**	26.18	7.21	18.94	382.2	223.8	59.0	1381	72.91	**52.75**	92.4	88.6	27.5%
		253.0	28.19	8.22	19.94	410.6	235.5	58.2	1438	72.13	**51.02**	103.9	100.0	29.2%
2*18W T8 lamps electronic ballast VS 188316, EEI=A2		**207.0**	36.59			181.0			2816		**76.96**	37.5	8.1	
	Rated voltage →	**230.0**	36.58			164.2			2817		**77.00**	37.8	9.4	
		253.0	36.53			149.7			2815		**77.07**	37.9	10.0	
2*18W T8 lamps magnetic ballast Helvar L36, EEI=B1		**207.0**	33.70	3.33	30.37	296.0	146.9	62.2	2330	76.72	**69.14**	61.3	51.2	9.9%
	Rated voltage →	**230.0**	42.24	5.34	36.90	379.0	179.2	58.6	2809	76.12	**66.50**	87.2	76.3	12.6%
	Φmag=Φelec →	**230.8**	42.70	5.58	37.12	387.0	180.9	57.9	2817	75.90	**65.98**	89.3	78.5	13.1%
		253.0	50.48	8.20	42.28	473.0	208.7	54.5	3169	74.95	**62.77**	119.7	108.5	16.2%
18W TC-D lamp electronic ballast Osram QT-T/E, EEI=A2		**207.0**	16.09			78.5			1064		**66.13**	16.2	2.3	
	Rated voltage →	**230.0**	17.75			78.2			1173		**66.11**	18.0	2.9	
		253.0	19.84			79.8			1276		**64.34**	20.2	3.7	
18W TC-D lamp magnetic ballast VS 508922, EEI=A2		**207.0**	17.71	3.33	14.40	165.7	165.6	107.4	982	68.19	**55.44**	34.3	29.4	18.8%
	Rated voltage →	**230.0**	21.69	4.96	16.70	204.7	195.1	101.7	1117	66.87	**51.48**	47.1	41.8	22.9%
	Φmag=Φelec →	**241.4**	23.86	6.01	17.80	225.7	208.9	99.0	1173	65.93	**49.18**	54.5	49.0	25.2%
		253.0	26.53	7.48	19.05	250.5	222.4	96.5	1229	64.51	**46.32**	63.4	57.6	28.2%

For measuring the T8 lamp in single-mode, a single-lamp electronic ballast was used instead of using the twin-mode ballast and connect only one lamp, which would have been possible but could have yielded wrong results. The most crucial results can be found in Table 3, represented as the light efficiency η_{tot} in lumens per watt electrical power intake of the whole lamp and ballast system. The light efficiency cannot be given in per cent because regarding brightness the human eye is differently receptive to light of different colours. Therefore the sensitivity of a standardised average eye is already integrated into the unit for brightness. This unit is called lumen (simply the Latin word for light). So the efficiency of lamps and lumiaires has to be given in lumens per watt. This and only this unit is adequate to assess which technical device provides the greatest brightness per power intake. Of course the share of ballast losses in the total power intake can be given as a percentage – as done in the last column of the table. However, with the electronic ballasts the required measurement of the lamp power, the ballast output power to the lamp so to say, was not possible due to the high output frequency. Therefore the efficiency η_{Lamp} of the lamp alone could not be calculated – but which is not relevant for the end user nor for an assessment of overall efficiency.

2.5 Results

The following results can be read and conclusions drawn from the table:

1. The advantages of the tandem configuration and of the TC-D lamp already found in the pre-measurement with respect to reactive power find their confirmation.
2. The magnetic ballast power loss increases highly over-proportionally to the systems operating voltage. At 253 V the power loss is usually double as high as at 207 V. Together with the slight increase of lamp efficiency η_{Lamp} the voltage reduction practice results as an efficient means of loss reduction for all magnetic ballast configurations.
3. When operated on rated voltage, a single 18 W T8 lamp is about 4% brighter with electronic than with magnetic ballasts. (This is the inverse result as found earlier with 58 W lamps [4], where the light output was 4% higher with magnetic ballasts.) On the twin electronic ballast compared to the magnetic tandem configuration the difference is negligible. The operating voltage on the tandem only has to be turned up to 230.8 V before the same brightness as with the electronic twin ballast is achieved.

Therefore when assessing the light efficiencies of the single-modes, two different approaches have to be considered:

4. Either the luminaires are operated at rated voltage in either case. The comparison will then be closer to what will usually happen in practice, though it is not objective. We are then talking about a systems power of 19.13 W with electronic ballast versus a systems power of 24.47 W with magnetic ballast. A payback time for the well over 5 W saved cannot be given, as the impact of the price premium for an electronic ballast upon the price for a complete lighting installation is subject to substantial variances. However, with an energy price of 10 c/kWh it takes 1872 operating hours to save the first Euro. This cornerstone can be used for the according conversions: At 5 c/kWh it takes 3744 hours, at 20 c/kWh it takes 936 hours to save 1 Euro and so on.

5. Or you calculate objectively. Nobody will increase the line voltage in order to achieve precisely the same brightness with the used/planned magnetic ballast as with the electronic ballast not used. The lighting planner is unlikely to include a few more lamps if the decision for magnetic ballasts has been taken, because the difference is so insignificant, but if done, then this would have approximately the same effect as if the same number of lamps were connected to a line voltage of 241.7 V, which would be equivalent to the difference between 19.13 W and 26.18 W systems power, say 7 W. So the real, effective »savings cornerstone« is then 1418 operating hours per Euro saved at 10 c/kWh.
6. Moreover, it becomes obvious that the limits of the EU directive, which are 24 W systems power in class B1 and 19 W in class A2, are in principle not complied with, neither by the magnetic nor by the electronic ballast. Only by being rather lenient accounting to metering inaccuracy the EEI classes can still be seen as just about fulfilled.

But by all means this mode of operation does not represent the optimal combination. The power loss in a 36 W ballast is not double the loss in an 18 W ballast (»Paradox of the Big Ballast«), about the triple advantage of the tandem mode not even to speak. Rather, the respective conclusions to above items 4 to 6 for the twin or tandem modes of two 18 W lamps will be:

7. Comparing the operation at rated voltage in either case, the difference between magnetic and electronic ballast operation is now only more some 2.5 W per system, whereas a system now comprises two lamps and one ballast (and two starters in the case of the magnetic ballast); say, the difference is only more 1.25 W per lamp. So with an electricity price of 10 c/kWh it takes 4000 operating hours to save one Euro per ballast or per every 2 lamps, respectively. Or, selecting a different example: At uninterrupted permanent duty with 8760 h/a and an electricity price which is usually quite inexpensive for such use, e. g. 6 c/kWh, one electronic ballast saves approximately one Euro per year.
8. Since brightness with magnetic and electronic ballast is almost equivalent at rated voltage, no distinction needs to be made and above values of point 32 still apply, which facilitates the comparison.
9. Although the directive provides a separate line with limits for two lamps being operated on one ballast, the values per lamp are identical to those for the single-mode operations as under item 6. Very much unlike with the configuration described under item 6, however, the limits are by far kept here: The electronic ballast remains well over 1.5 W below the class A2 limit, the magnetic ballast even falls 3.5 W below the B1 limit.

On the TC-D lamp the following can be observed:

10. The efficiency is about 5% to 10% poorer than that of the T8 lamp. This may be due to the compact design which leads to a part of the light generated hitting the lamp itself.

11. Here the use of the electronic ballast results in an uncommonly high saving of 28% on equal voltage or 34% at equal light output, respectively. It by far fulfils the requirements for class A2, while the magnetic one does not really match the limit for class B1. This magnetic ballast may have been designed a bit too small in favour of facilitating the design of very small luminaires (Figure 7 top right), and in electrical engineering skimping on active material (copper and magnetic steel) always comes at the price of reduced efficiency. It has to be considered, however, that these two measurements possibly cannot really be compared because they could not be carried out on the same lamp. The TC-D lamp for magnetic ballast operation is equipped with an integrated starter and therefore has only two connections (Figure 7 left). The starter is wired internally. The version for electronic ballast operation requires four pins.
12. Unlike the other electronic ballasts used in this test, the one for this lamp is not equipped with an electronic power stabilisation to offset variances of the input voltage.

3 Conclusions

It has become obvious that the difference between the poorest and the optimal combination of lamps with magnetic ballasts covers a much wider range than the transition from magnetic to electronic ballasts. Electric losses may range as high as 50% and as low as 14% of the measured total luminaire or systems power. It is therefore important to select the right combination of a lamp and ballast, since in a variety of cases different lamps can be operated with the same ballast and vice versa. The overall light efficiency varies even wider, therefore:

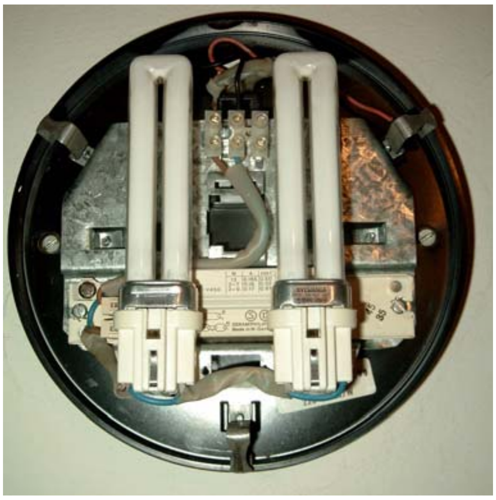

Figure 10 One ballast suffices for two smaller lamps, reducing the levels of both reactive power and active losses below the level which otherwise one lamp alone would cause

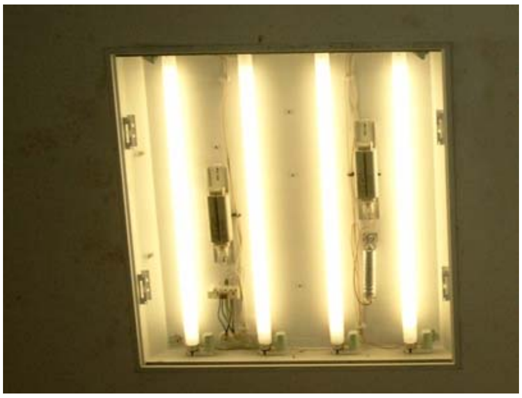

Figure 11 Two ballasts and one capacitor are enough to operate four 18 W lamps in this luminaire very economically, both from an energy efficiency **and** from an initial investment cost viewpoint

- Wherever the opportunity exists to vary the combination of lamps and ballasts, as a rule it is better to operate a higher lamp power rating on a given ballast than a lower rating.
- Wherever possible, the tandem configuration should be preferred to single-mode (Figure 10, Figure 11).
- Adding to this, best available EEI ballast classes should be selected (although the impact of this point is minor than that of the former two).
- However, to identify a payback time for the use of electronic ballasts is difficult, as the pricing often includes other factors in addition to the price difference between magnetic and electronic ballasts. Some luminaires are only available with electronics. It may even require a surcharge to get magnetics as an extra. In such cases it seems to be time to look for a different supplier if you prefer magnetic ones for reliability or EMC reasons. However, when considering to pay a price premium for electronic ballasts in order to improve energy efficiency, it remains to also consider that, depending on the assumptions you make, it takes between 1000 and 10,000 hours of operation to save 1 Euro of electricity costs.

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GLARE SOURCE IN A WINDOW FOR EVALUATING DISCOMFORT GLARE

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This work aims to propose a practical method of selecting glare source in a window having non-uniform luminance. Experiments were conducted using a luminous body divided into two parts. Each part of the luminous body has the same size but different luminance. The degree of discomfort glare from the luminous body was investigated. The result shows that the part with lower luminance is not considered as a glare source when the part has luminance less than 49% of the luminance of the higher luminance part.

Keywords: *glare, discomfort glare, non-uniform luminance*

1. INTRODUCTION

Control of discomfort glare from daylight is an important issue and dominates the quality of daylighting. In general, glare sources of daylight i.e. windows are large and have non-uniform luminous distribution. The sky and the obstacles seen through windows usually have different luminance. Moreover, the luminance distribution of the sky is not uniform [1].

The Unified Glare Rating (UGR) [2] system has been recommended internationally to evaluate the degree of discomfort glare from indoor lighting installations. The UGR system is applied to electric lighting installations, and only a few methods have been investigated for evaluating discomfort glare from windows.

The Daylight Glare Index (DGI) [3] and Predicted Glare Sensation Vote (PGSV) [4] are well known methods to predict discomfort glare from windows. However, these methods are in limited use because these have been developed for evaluating a large glare source with uniform luminance.

In the DGI and PGSV, there is no suggestion about how to determine the luminance of a window having non-uniform luminance distribution. The luminance of a window is a main factor influencing the degree of discomfort glare. When the luminance of a window is defined differently according to the appraisers, the degree of discomfort glare varies widely even in the case of the same window. It is necessary to elucidate the glare source in a window and the method of determining the luminance of the glare source.

This work aims to propose a practical method of selecting glare source and of determining the luminance of glare source in a window having non-uniform luminance.

2. EXPERIMENTAL METHODS

The experiment contained two kinds of measurements: the degree of discomfort glare from the model window with non-uniform luminance is measured, and the ratio of luminance is measured when the observers perceived the difference in luminance.

2.1. Model Windows

A model window was assumed to be a large glare source (Figure 1). The window's size was 90cm * 90cm, and white paper was pasted on its surface to produce diffuse light (Figure 2). Sixty-four incandescent lamps were installed inside the window. The luminance of the window can be fixed specifically from a wide range of 0-7400 cd/m^2. The surface of the window was divided into two surfaces, right and left, and the luminance was set differently. The luminance of each surface is controlled by the number of papers pasted on it. The size of the window is controlled by the distance from the eyes of observers to the window. Table 1 shows the experimental conditions.

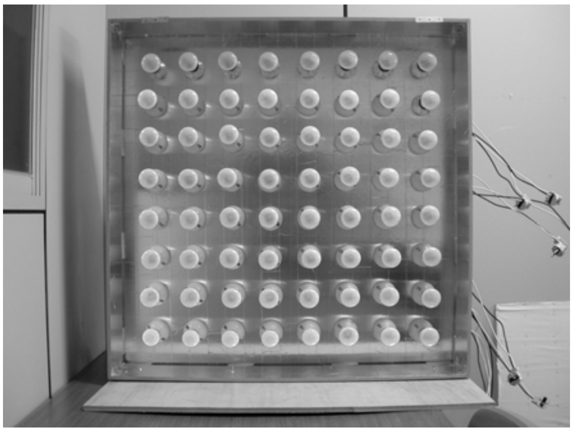

Figure 1 Luminance body for the experiment

Table 1 Experimental condition

Luminance of standard part (0.165sr) [cd/m^2]	Luminance of comparative part (0.165sr) [cd/m^2]	Ratio of luminance [-]	Size of window [sr]	Vertical illuminance [lx]
5830	5830	1.00	1.86	9540
5830	5830	1.00	0.68	3820
5830	5830	1.00	0.33	1900
5830	5830	1.00	0.19	1260
5830	5830	1.00	0.12	890
5830	5830	1.00	0.33	610
5830	2540	0.44	0.33	460
5830	1560	0.27	0.33	400
5830	540	0.09	0.33	350
2970	2970	1.00	1.86	1430
2970	2970	1.00	0.68	600
2970	2970	1.00	0.33	290
2970	2970	1.00	0.19	220
2970	2970	1.00	0.12	160
2970	2970	1.00	0.33	290
2970	1790	0.60	0.33	210
2970	1050	0.35	0.33	180
2970	370	0.12	0.33	150

Figure 2 Experimental set-up

2.2 Observers' Characteristic
Twenty-one observers volunteered for the experiment. The observers' age ranged from 20 to 40, the average being 25.5. Among them, two observers had contact lenses on during the evaluation.

2.3 Criteria for the Evaluation
The observers evaluated discomfort glare from the window by the multiple criterion scale (Table 2). The degree of discomfort glare is the numerical scale adopted for this experiment.

Table 2 Multiple criterion scale of the evaluation

Degree of discomfort glare	Criterion
4	Just intolerable
3	Just uncomfortable
2	Just acceptable
1	Just perceptible

2.4 Experimental Procedure
The observers were asked to sit on the chair and performed a task of transcribing a book for a minute. After the task, they raised their heads and looked at the center of the window for 5 s, and evaluated the discomfort glare on an evaluation sheet. Each observer repeated the evaluation under the eighteen conditions (Table 1). The different luminance levels were presented randomly so as to control for the effect of presentation. The period of time to complete the evaluation sheet for each observer was 30 min.

3. RESULTS AND DISCUSSION

The relationship between the degree of discomfort glare and the size of the window is represented in Figure 3. The degree of discomfort glare in the Y-axis increases linearly as the size of the window in the Y-axis increases. When the luminance of the window is 5830 cd/m^2, 2970 cd/m^2, the inclination of the regression line in fig. 3 is 1.83, 2.24, respectively. The average inclination is 2.04. This means that the degree of discomfort glare increases by 2.04 when the size of the window increases 1 logarithm. Therefore, it is predicted that the degree of discomfort glare decreases by 0.61 when the size of the window is reduced by half.

Fig.4 shows the relationship between the degree of discomfort glare and the ratio of lower luminance to higher luminance in the window. The degree of discomfort glare increases linearly according to the increase of the ratio of luminance.

On the basis that the degree of discomfort glare decreases by 0.61 when the size of the window is reduced by half, it is predicted that the degree of discomfort glare decreases from 2.6 to 1.99 when the size of the window having luminance 5830 cd/m^2 is reduced by half. Also, the degree of discomfort glare decreases from 1.93 to 1.32 when the size of the window having luminance 2970 cd/m^2 reduces by half.

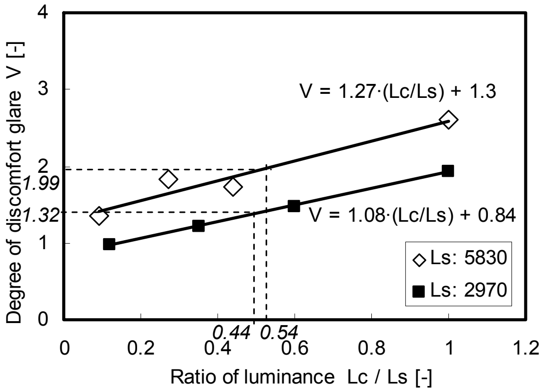

Figure 3. Relationship between the degree of discomfort glare and the size of the window

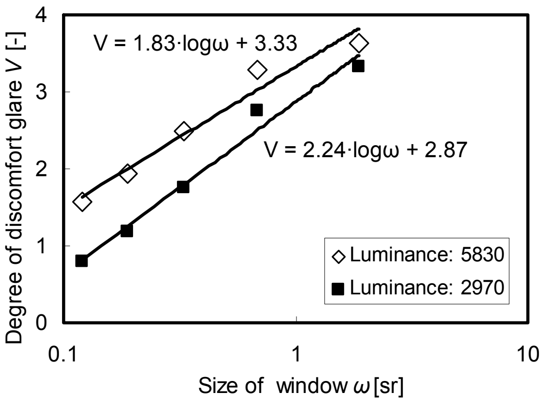

Figure 4. Relationship between the degree of discomfort glare and the ratio of luminance
(Ls: higher luminance, Lc: lower luminance)

In Figure 4, the ratio of luminance is 0.54 when the degree of discomfort glare is 1.99 on the upper regression line. Also, the ratio of luminance is 0.44 when the degree of discomfort glare is 1.32 on the lower regression line. The average ratio of luminance is 0.49. These results suggest that the part with lower luminance is not considered as a glare source when the part has luminance less than 49% of the luminance of the higher luminance part in the window.

4. CONCLUSION

From the results in this work, it can be concluded that glare source in a window results from the highest level of luminance down to a level which is 49% of that highest level of luminance.

ACKNOWLEDGEMENTS

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LIGHTING AUDIT

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The paper presents the types of audit for lighting systems, pointing out their main characteristics. The steps that auditors have to take are concisely presented, together with the lighting audit forms. The theoretical aspects presented in the paper were applied to a number of ten lecture rooms of the Technical University of Cluj-Napoca. The redesignment of the lighting system was submitted after the audit has been completed, in order to improve the illuminance level recommended for the specific activities of these rooms.

1. Introduction

The main purpose of a lighting audit is to gather information concerning the characteristics and the current condition of lighting systems in order to compare them with given standards of illuminance.

An improvement or redesigning plan can be proposed after the audit has been finished.

Other purposes regard the potential financial savings that can be achieved by the upgrading the current lighting system or benefits such as employee productivity.

As part of the modernization process, the audit supplies data to determine costs and benefits of upgrading or redesigning the lighting system.

Occasionally, audits are performed after an upgrade is installed. The reason for performing an audit after a relighting or upgrade is to verify its performance and compare it with the baseline conditions.

2. Type of Audits

There are three types of audits which form a hierarchy from simple to complex, in this order: the walk-thru survey, the intermediate audit (mini-audit) and the comprehensive audit.

The purpose or reason for performing an audit determines which type is required. If the purpose is to establish whether a lighting upgrade is necessary or if the owner simply wants a “check-up” of the lighting systems, then a walk-thru survey usually accomplishes these purposes.

On the other hand, a comprehensive audit will be used for relighting. The costs may also dictate the type of audit. Surveys are less time-consuming and therefore less expensive than the more time-consuming comprehensive audits.

2.1 The Walk-Thru Survey

The walk-thru survey is the simplest type of audit and it is usually performed while the auditor simply walks through the analyzed space for collecting a minimum amount of data. A brief report describes the existing system, outlines the suggested improvements and reports the estimated payback.

2.2 The Intermediate Audit (Mini-Audit)

The intermediate audit is more detailed and the information is collected by a team of two or three persons.

The financial analysis is more than a simple payback analysis and calculations are made for the entire project, not only for some of the equipments. The report includes equipment inventories, power densities and costs evaluations.

2.3 The Comprehensive Audit

This type of audit is performed when the highest level of detail is required and is conducted by small teams of two or three persons. The lighting standards and worker's productivity are equally important to the lighting equipment's performance. All lighting equipment is fully identified and a detailed evaluation of lighting quality improvements is outlined. The assessment of daylighting is optional, depending on the purpose of the audit [1]. An extensive analysis is performed, including the life-cycle costs.

The report describes the condition of the existing lighting systems and outlines several upgrading possibilities, including the lighting system redesignment, which can be made through CAD software.

3. The Lighting Evaluation Process

Evaluating a lighting system is a multi-step process. At its minimum, the evaluation is a three-step procedure: performing a lighting audit, identifying opportunities for improvements and evaluating savings and potential payback.

3.1 Performing a lighting audit

The characteristics of each lighting system need to be evaluated, including operating conditions, operating hours and maintenance.

The action plan can be a simple report or a lighting management plan. Lighting management has a broader acceptance than lighting energy conservation since it includes the lighting quality of the studied environment, the visual performances and the company's priorities as well.

3.2 Identifying opportunities for improvements

Improvements are the changes that raise the existing conditions of the lighted environment to a better quality. There are several bases for identifying opportunities for improvements; they can be categorized in terms of quantitative and qualitative identification.

3.2.1 Quantitative identification

There are two measurable bases for identifying the opportunities for improvements: power density and light levels (illuminance).

a. Power density

Power density, PD, is the power allowance for a building, measured in Watts per square meter (W/m^2). The more efficient the lighting equipment is, the lower the power density. The power density of lighting systems can be used by the auditor as a screening measure.

b. Light level or illuminance

Measuring illuminance during the audit will allow the auditor to determine if light levels are appropriate in each of the studied spaces by comparing them to the given recommendations.

The analysis includes information about the type of space and how the space is used, the visual tasks and other factors, such as the age of the occupants, the accuracy in performing a given task and surface reflectance.

For spaces that are found to be underlighted, the redesignment must ensure sufficient light for the safety and security of occupants and visitors.

c. Lighting controls

Lighting systems that are not controlled may waste energy and create a negative image over the company or organization.

The absence of efficient lighting controls provides the opportunity of an improvement and an analysis will determine from all the data collected what type of control is recommended.

d. Switching opportunities

The information about the switching methods used in each space allows the auditor to determine which method can best control the lighting in the given space: occupancy sensors, timers or centralized control systems.

e. Dimming

The option of changing light levels in individual spaces has become available through electronic dimming equipment.

3.2.2 Qualitative identification

Qualitative identification of opportunities requires subjective judgments of lighting systems. Lighting quality considers visual aspects that are highly subjective and not easily quantified. It is possible to evaluate several quality attributes or characteristics, including ceiling reflections, glare, color and color rendering, lamp flicker, luminance ratios and visual comfort.

3.3 Calculating savings and potential payback

Lighting costs can be divided into first costs and operating costs, consisting of energy, labor and lamp costs.

3.3.1 Electricity costs

The most important components of monthly billings include energy usage, peak demand charges and power factor penalty.

3.3.2 Economic decision statistics

There are two economic decision statistics that are used in lighting evaluation: the simple payback for long-term projects and life cycle costs for lighting upgrades or relighting projects.

a. Simple payback

Simple payback relates to how long it takes to recover an initial investment in a cost-saving measure, taking into consideration the annual savings and the currency's stability.

b. Life cycle costs

The life cycle costs is an economic method of a project's evaluation that takes into account all costs arising from the ownership, operation, maintenance and disposal of a lighting project, considering long-term performance.

4. The Intermediate Audit (Mini-Audit)

4.1 Description

When performing this type of audit, lighting equipment inventories should be either estimated or counted. The number of operating hours has to be obtained as well.

The auditors should look for upgrade opportunities based on equipment types. The intermediate audit is the level in which auditors start to record their subjective judgements over the tasks performed in that space, the state of maintenance, the surfaces' finishing and the overall lighting quality.

Reports include equipment inventories, power densities, limited evaluation of upgrade or relighting alternatives and a payback evaluation. The report compares the existing lighting system's efficiency with the potential efficiency of the redisgned lighting system.

4.2 Lighting audit forms – office lighting checklist

The office lighting checklist is a form used for intermediate and comprehensive audits of office lighting. It records general information about the office: its dimensions, surface finishing, cleanliness and illuminance readings. The data collected includes the following:

1. Building and office identification;
2. Room dimensions: length, width, ceiling height;
3. Room surface finishing: ceilings, walls, floors (identifying them as light-colored, medium-colored, or dark-colored) or room reflection coefficients;
4. Area cleanliness: very clean, clean, average, dirty, very dirty;
5. Illuminance.

Another section of the checklist consists of information about lamps and fixtures (luminaires): lamp's power (in Watts), number of lamps per fixture, type of lamp, length and diameter, color temperature, color rendering index, depreciation. Other data is about the quantity of luminaries in the office, optical control, center-to-center spacing in the lengthwise direction and widthwise direction, the number of operating hours (hours per week and weeks per year).

5. Intermediate Audit for Lecture Rooms

The intermediate audit has been used for relighting several lecture rooms belonging to the Faculty of Electrical Engineering in the Technical University of Cluj Napoca. For a number of ten lecture rooms, there were measured the room dimensions - length, width, ceiling height - and illuminance - E_{med}. There were gathered informations about the number of luminaires, room surfaces' finishing (ceiling, walls and floor), area cleanliness, and lamp's Watts, number of lamps per fixture, type of lamp, length and diameter, color temperature.

All the collected information is given in tables 1 and 2.

Table 1 Room dimensions, surfaces, installation data and illuminance.

Room index	Room dimensions			Mn. height m	Reflections coefficient			Area clean	E_{med}, lx	E_{max}, lx	E_{min}, lx	No. col.	No. rows	Ltwise spac, m	Wtwise spac, m
	Lgth, m	Wdth, m	Ceil. height.m		Ceiling ρ_c	Walls ρ_w	Floor ρ_f								
318	10.50	6.50	4.20	3.20	0.80	0.60	0.30	C	215	290	40	2	2	5.45	3.25
P01	10.50	9.80	4.20	3.60	0.80	0.70	0.52	C	237	340	135	3	6	1.95	1.30
P02	10.50	9.80	4.20	3.60	0.80	0.70	0.52	C	237	340	135	3	6	1.95	1.30
40	12.76	8.42	6.00	5.40	0.80	0.70	0.52	C	309	530	100	3	5	1.80	1.70
41	12.76	8.42	6.00	5.40	0.80	0.70	0.52	C	309	530	100	3	5	1.80	1.70
356	12.00	6.25	4.25	3.65	0.80	0.70	0.52	C	207	245	82	1	3	3.20	-
Bll	14.80	9.15	6.00	5.00	0.80	0.70	0.52	C	269	255	70	-	-	-	-
159	9.00	6.70	4.24	3.64	0.80	0.70	0.52	C	330	550	140	3	3	1.8	1.34
366	7.35	6.45	4.20	3.60	0.80	0.70	0.52	C	195	210	73	1	2	4	-
46	9.20	6.40	4.20	3.60	0.80	0.70	0.52	C	237	275	68	2	2	4.05	2.45

It can be observed in the filled up check lists that the measured illuminance in the lecture rooms was not respecting the recommended value for the type of activity performed (the recommended value is 500 lx).

Table 2 Luminaires information and energy consumption.

Room index	Luminaire						Burn hours		Total Load, W	Power density, W/m	Energy kWh/Year
	Type	Size m	Load/ luminaire W	Lamp/ luminaire	No. luminaires	Tc, K	Hrs/Wk	Wks/Yr			
318	TPX 200_236	1.6	79	2	4	6500	50	40	316	4.63	632
P01	FIRA-03_236	1.18	84	2	18	4000	50	40	1512	14.69	3024
P02	FIRA-03_236	1.18	84	2	18	4000	50	40	1512	14.69	3024
40	TPS 672	1.55	77	2	15	3500	50	40	1155	10.75	2310
41	TPS 672	1.55	77	2	15	3500	50	40	1155	10.75	2310
356	FIRA-03_236	1.18	84	2	3	6200	50	40	252	3.36	504
Bll	FIRA-03_236	1.18	84	2	18	4000	50	40	1512	11.16	3024
159	FIRA-03_236	1.18	84	2	9	4000	50	40	756	12.53	1512
366	FIRA-02_236	1.27	87	2	2	6500	50	40	174	3.67	348
46	FIRA-01_265	1.18	145	2	4	6500	50	40	580	9.85	1160

Therefore, a lighting system redesignment was performed in all ten lecture rooms. There were taken into account several types of luminaries, lamps and layouts. After relighting, the illuminance levels and uniformities have become appropriate to the current recommendations for the type of activity performed in the lecture rooms.

Table 3 presents the results for one of the several solutions obtained after relighting. The luminaries that have been used, X-tendolight TPS 498, have a large luminous intensity distribution and 2 tubular fluorescent lamps T8, of 36 W each, with a color rendering index of 80 and a light temperature of 3000 K. It is also given the amount of energy used by the new lighting systems, considering the number of operating hours per year.

Table 3 Luminaires information and energy consumption after light system redesign.

Room index	Luminaire						Burn hours		Total Load, W	Power density, W/m	Energy kWh/Year	E_{med}, lx	U_0
	Type	Size m	Load/ Luminaire W	Lamp /luminaire	No. luminaires	colour	Hrs/Wk	Wks/Yr					
318	TPS 498 2X TLD 36 W	1.358	85	2	12	830	50	40	1020	14.94	2040	526	0.73
P01		1.358	85	2	16	830	50	40	1360	13.21	2720	568	0.70
P02		1.358	85	2	16	830	50	40	1360	13.21	2720	568	0.70
40		1.358	85	2	18	830	50	40	1530	14.24	3060	507	0.67
41		1.358	85	2	18	830	50	40	1530	14.24	3060	507	0.67
356		1.358	85	2	6	830	50	40	510	10.75	1020	469	0.75
Bll		1.358	85	2	16	830	50	40	1360	10.04	2720	452	0.69
159		1.358	85	2	12	830	50	40	1020	16.92	2040	492	0.64
366		1.358	85	2	6	830	50	40	510	10.75	1020	469	0.75
46		1.358	85	2	12	830	50	40	1020	17.18	2040	515	0.65

6. Conclusions

The benefits of redesigning the lighting system consist in a higher level of illuminance, according to current standards, not in energy savings. Neither dimming, nor switching methods are recommended for the spaces, due to the specific educational programs performed in the lecture rooms.

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AN EVALUATION ALGORITHM ON THE RIGHT OF VIEW USING GRAPHIC PROGRAMS

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The right of view is one of the most important factors in providing residents with psychological comfort and stability in residential environment. At present, apartment housings account for more than 50% of housing in Korea. With the construction of high-rise apartments escalating, urban residential areas have become packed with high-rise buildings. As a result, disputes over the infringement of the right of view have been on the increase. According to a court judgement, the view ratio is zero when one's view (with no eye movement) is completely blocked by other buildings. According to the court, when it is more than 40%, the view ratio falls within the range of tolerance. The view range can be analyzed in a disputed area by comparing the view range of the area before the building in question is constructed with that after it is constructed. Therefore, the court uses the view ratios as reference data, by calculating them based on computer simulations, measuring the degree of infringement on the right of view, and analyzing the situation by considering all of these. However, computer simulations of the view range can differ, depending upon the accuracy of the input data - including the types and height of buildings, the distance between buildings, and the altitude - and the characteristics of simulation programs. In this paper, Autodesk VIZ Program and a view program that developed by the authors were used for simulation. The validation was verified to compare the outcome of the simulation with that of an on-spot survey at the apartment housings.

***Keyword**: View right, Visual privacy, View out, Apartment Housing*

1. INTRODUCTION

View is one of the architectural environmental elements affecting human living. As living standards are improving, concern about the quality of life is increasing. Accordingly, disputes over the right to enjoy sunshine and the right of view are increasing. Especially in urban centers, as buildings become increasingly higher, there are many cases of infringing on the right of view that was secured before they were built. In general, if the right of view is infringed upon, one feel psychologically pressured and confined. If the right of view is infringed upon by neighboring buildings, the seriousness rests with continuous infringements instead of one-time infringement, as long as there are buildings being constructed.

If scenery worth viewing exists already and the value of the present building depends considerably on the scenery, infringement on the right of view by construction of a new building could affect the property value of the original building.

There are no established views on the method of measuring the extent of the infringement upon the right of view, and there are actually many difficulties and constraints ensuing from measuring it at the site where dispute has occurred. Therefore, computer simulation is frequently utilized to analyze the extent of the infringement upon the right of view through evaluation of the right of view. With computer simulation, it is possible to measure the view infringement regardless of the construction schedule of the building and view evaluation is possible by assuming the views before and after construction. Consequently, serviceability is high. However, the method and standard for 3D simulation that enables access in various methods are not established and the evaluation standards for evaluating the right of view from the apartment that has the right of view infringed upon are not established either.

This paper aims to propose an evaluation algorithm using 3D simulation program. For this, evaluation of the right of view was made by using the case of J Apartment Housing and validation was verified by comparing the view conditions of actual apartment housing.

1.2. Research Design and Methodology

① Survey and measurement were conducted on the actual condition of the buildings around the J Apartment Housing located in Yongin City, Gyeonggi-do that was selected as an evaluation object, and visits were made to the management office, field office and design office to collect and analyze data including design documents to utilize them as input data. Also, explanation was given about the Autodesk VIZ as a simulation program and a view program developed by the authors.

② 3D modeling for view simulation of S Apartment Housing located southeast of J Apartment was conducted using the results of field trips to the site and analysis of drawings. A simulation method was presented.

③ Evaluated the view conditions before and after the construction of S Apartment Housong.

④ Compared the view conditions of the actual apartment and the computer simulation based on the same location to verify validation of the findings.

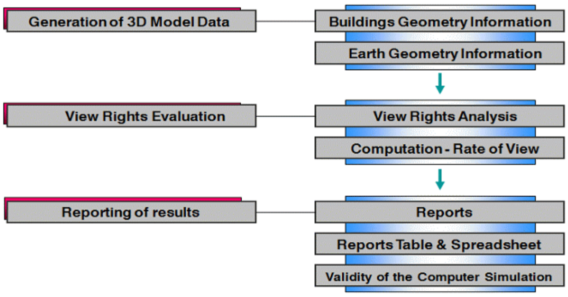


Figure 1 View analysis process

Figure 2 Apartment house layout

2. SUMMARY OF THE APARTMENT HOUSING

2.1. Selection of the Apartment Housing

Selection was made of J Apartment Housing of Yongin City, Gyeonggi-do, the building expected to have its view infringed on. Building 105 of J Apartment House was built with 14 floors, and Building 115 of S Apartment Housing (19 stories high) was built southeast of the J Apartment Housing.

2.1.1. Selection J Apartment Housing

J Apartment Housing consists of 6 buildings and 478 house units with 9 to 18 floors. The story height of each floor is 2.6M for the 1^{st} to 15^{th} floor and 2.8M for the 16^{th} or higher floors due to installation of sprinklers. 6 buildings of the J Apartment site, it was expected that building 105 would have its view infringed upon. That building consists of 14 floors and 6 rows and has an L layout. Of the 96 house units of Building 105 of J Apartment Housing, 14 house units on row 5 and 14 households on row 6 are house units that are expected to have the view infringed upon due to new construction of buildings 114 and 115 of S Apartment Housing.

Building 105 of J Apartment Housing is located west of building 115 of S Apartment House with parking lots for each located between the buildings.

2.1.2. S Apartment Housing

Buildings 114 and 115 of S Apartment Housing located southwest of J Apartment Housing were built anew with 19 floors aboveground and are expected to infringe upon the sunshine and view of building 105 of J Apartment Housing. The shape of the building is as shown in Photo 2.

Photo 1 Building 105 of J Apartment House

Photo 2 Buildings 115 and 114 of S Apartment House

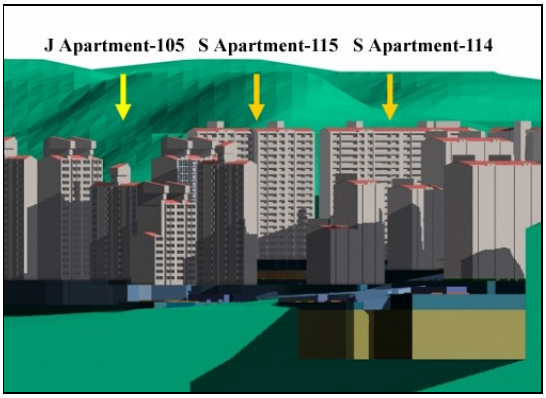


Figure 3 West Elevation

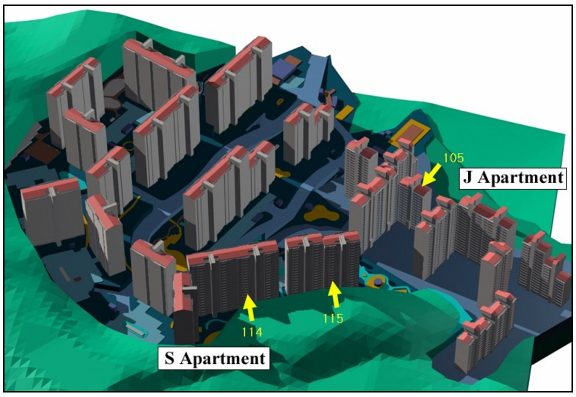
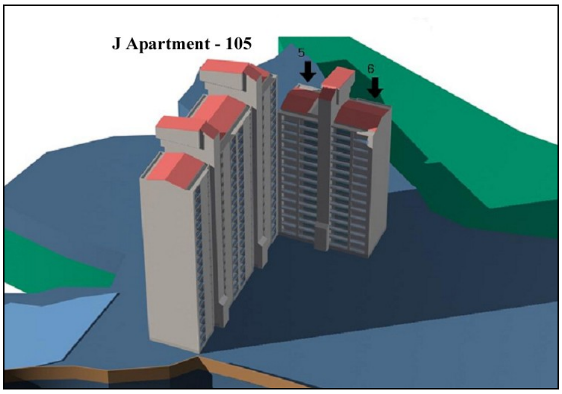
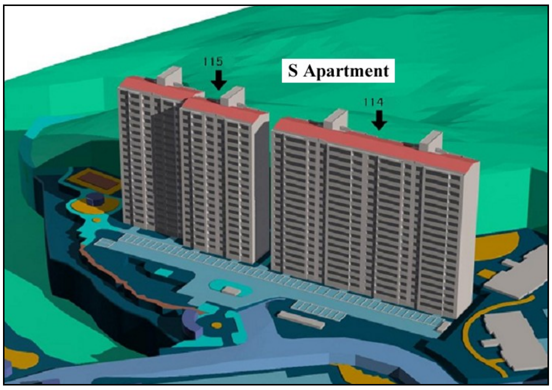


Figure 4 Bird's Eye View



(a) J Apartment House - Existing Building



(b) S Apartment House – New Building

Figure 5 Bird's Eye View

2.2. View Standards

2.2.1. Legal Aspect of the Infringement upon View

Supreme Court Judgment 2003Da6302 passed on Sept. 13, 2004 set forth the requirements that land or building should have for a view benefit by ruling, "If scenery or view that has been enjoyed by the owner of any land or building is objectively acknowledged to have a value as a living benefit, it can be an object of legal protection. Such a view benefit should not be an object of legal protection, unless it is acknowledged that a specific place has in principle a special value in viewing outside, and the view benefit that the owner or occupant of the building is enjoying from the building has such an importance as to be acknowledged as a socially accepted idea as in the case that the building was constructed in the place with an important purpose of enjoying such a view benefit."

2.2.2. How to Measure the Infringement on View

There are two methods of measuring the infringement on view as follows:

① The view ratio is regarded as 0% if the field of view is completely blocked by obstacles (with no eye movement) and as 100% if it can be seen completely.

② With number 0 for no buildings to due south and 10 for complete infringement by buildings, it is possible to express the extent numerically by classifying 0~2 as normal and 3~5 as bad, etc.

2.2.3. Tolerance limit to view infringement

① Seoul High Court Judgment 99Na5267, 52574 (combined) passed on July 7, 2000 ruled that the view ratio is 0% if the field of view is completely blocked by other buildings with the eye not moving, and if it is 40% or higher it is not unlawful as it is within the tolerance limit.

② Changwon District Court Jinju Branch Judgment 98GaHap980 passed on November 26, 1999 ruled that, by saying that a view is a condition in which you can see scenery by avoiding the opposing building, unlawful infringement is the case of the household where the view from at least one place or more of any of the center of the living room and from the sitting room in front of the living room of the infringed building is blocked 100%.

③ In Seoul High Court Judgment 94Na11906 passed on March 29, 1966 and Seoul District Court Euijeongbu Branch Judgment 2000GaHap2792 passed on May 9, 2001, a perforation rate is measured as a method of measuring view infringement. With a perforation rate of 0 for no buildings and 10 for high-rise buildings in due south, it was ruled that the tolerance limit was exceeded if a certain standard of numerical value was exceeded.

3. VIEW EVALUATION METHOD

3.1. Selection of View Simulation Programs

As simulation programs for view evaluation, AutoCAD and Autodesk VIZ, which are generally used in architectural design, were selected, and a self-developed view program was selected to calculate the view area of the building to be evaluated.

The program was to calculate the number of pixels of a specific color of image, and display it by ratio. Since it is possible to control the color of the perforated portion when an image is generated by using the render function of Autodesk VIZ, we can obtain the ratio for a specific color. The program was made by using the Bitmap function of Visual Basic 6.0, and the area ratio was displayed by searching the white color on the monitor in dot unit based on a resolution of 1024×768.

3.2. Method of Evaluating the View of the Target Apartment House

3.2.1. Input of Building Data

After confirming whether the layout, floor plan, elevation, sectional view, survey plan, etc. of the apartment house agree with the actual site, an accurate 3D model was made using AutoCAD. For the orientation and location of the apartment house site, I referred to the digital map of the same number of lot manufactured by the National Geographic Information Institute of the Ministry of Construction and Transportation. Layer setting for simulation on Autodesk VIZ was divided by building. Since the view from the J Apartment House should be accurately expressed, precise modeling was made of the structure of the roof and penthouse of S Apartment Housing.

3.2.2. Setting View Analysis

The model made on AutoCAD was linked with Autodesk VIZ by using the file link manager function. The scene (as observed when a person 170cm tall looked out the window in the perpendicular direction while sitting in the center of the living room of the household to be evaluated) was created by computer simulation to analyze the view ratio of each household. The height of the analysis point was set as the value obtained by adding the eye height (0.9 m) with the observer sitting on the living room floor of each room (the living room floor according to the drawing obtained).

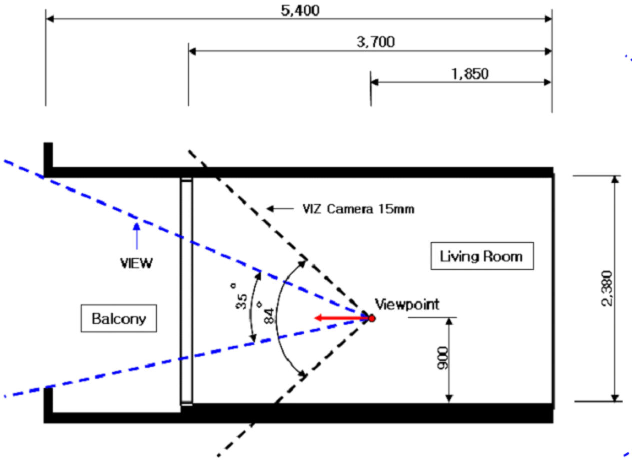


Figure 6 Section

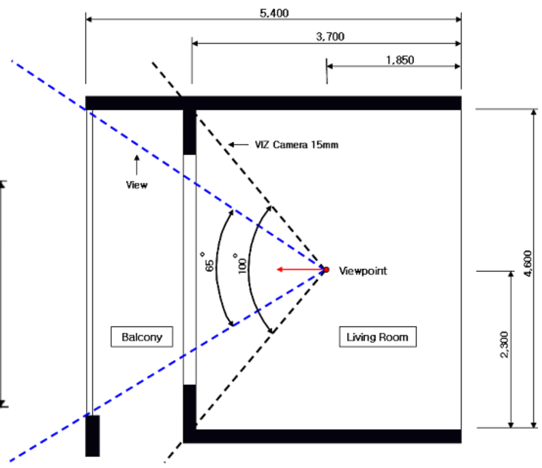


Figure 7 Plan

3.2.3. View Analysis Model

An accurate 3D model is required for measuring the view. For this, a site model was made by using the digital map marked with contour lines of the National Geographic Information Institute to find out the view condition from each houseunit that has its view infringed upon before S Apartment Housing was constructed anew.

The digital map of the National Geographic Information Institute not only has the elevation of contour line marked but also is made three-dimensionally, so it is possible to make a three-dimensional site model. By using the drape function of Autodesk Architectural Desktop program, precise modeling was made of the topography on the 3D digital map.

4. EVALUATION OF RIGHT OF VIEW

4.1. Summary of View Evaluation

The view ratio was calculated as a percentage (%) of the area not obstructed by the existing and new buildings to the area viewed out of the window. At this time, the area viewed out of the window of the living room was calculated as the opening area. The mountains that existed before new construction of the infringing building were included with other view elements such as the sky. The results of analysis were organized by household opening area, view ratio (%) before new construction, view ratio (%) after new construction and infringement on view ratio (decreased view ratio) due to new construction.

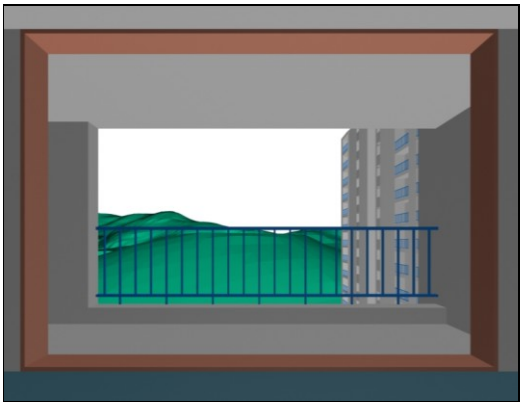


Figure 8 View before new construction S Apartment House

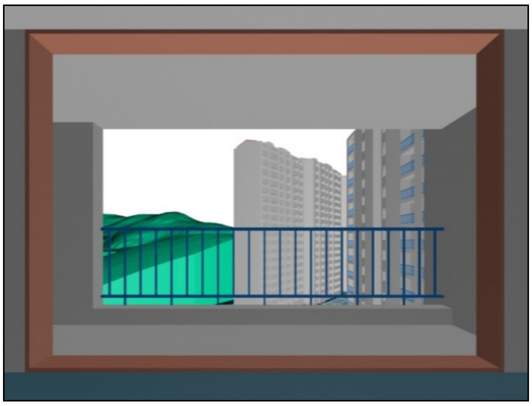
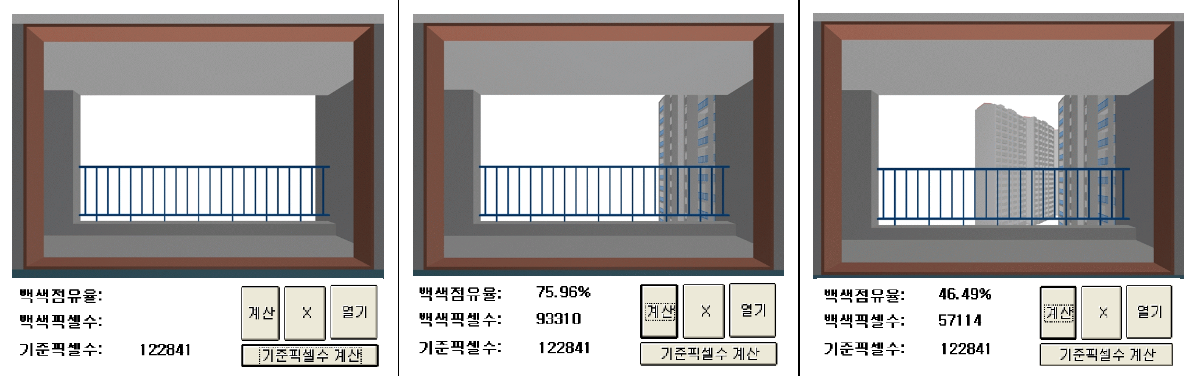


Figure 9 View after new construction S Apartment House

4.2. Calculation of View Ratios Using View Program

To calculate the view ratio, the reference number of view pixels should be calculated. In the present paper, the total number of white color pixels of the outside seen through the opening on the side of balcony window from the center of the living room was calculated and then this was set as 100%.

Building 105 of J Apartment House is an L-shaped apartment house, so part of the opening view on the side of balcony of the living room is already blocked by the building itself. So this was re-calculated based on the reference number of pixels. The calculated white color occupation ratio becomes the view ratio of the apartment house itself.



(a) Reference View of J Apartment House	(b) View Ratio by the Building Itself of J Apartment House	(c) View Ratio After New Construction S Apartment House

Figure 10. Calculation of View Ratios

The white color occupation ratio is calculated by calculating the number of white color pixels based on the reference number of pixels including the newly constructed apartment house. The calculated white color occupation ratio becomes the view ratio with the newly constructed apartment house included.

To generate view images, free camera was used on Autodesk VIZ and after positioning it accurately at the center of the living room, variables were input as shown in <Table 1>.

Table 1 Autodesk VIZ - Camera setting

Items	Input Parameters			
Lens	15mm			
FOV	↔	100.389 deg	↕	83.974 deg
Type	Free Camera			
Installation location	Center of living room			
Installation height	900mm			

Table 2 Row 5 of J Apartment House View Ratios Before and After New Construction of S Apartment Housing

Row	Number	Before New Construction of S Apartment Housing (%)	After New Construction of S Apartment Housing (%)	Decreased Due to New Construction of S Apartment Housing (%)
5	105	63.99	43.52	20.47
	205	59.35	38.18	21.17
	305	64.39	42.18	22.21
	405	69.39	45.87	23.52
	505	69.34	44.40	24.94
	605	69.36	42.93	26.43
	705	69.41	41.51	27.90
	805	69.31	40.11	29.20
	905	69.36	39.18	30.18
	1005	69.36	38.71	30.65
	1105	69.37	38.95	30.42
	1205	69.37	40.20	29.17
	1305	69.64	42.00	27.64
	1405	77.13	51.23	25.90

Table 3 Row 6 of J Apartment House View Ratios Before and After New Construction of S Apartment Housing

Row	*Number*	*Before New Constructio n of S Apartment Housing (%)*	*After New Construction of S Apartment Housing (%)*	*Decreased Due to New Construction of S Apartment Housing (%)*
6	*106*	*88.48*	*63.87*	*24.61*
	206	*86.86*	*61.57*	*25.29*
	306	*85.57*	*59.06*	*26.51*
	406	*85.07*	*57.08*	*27.99*
	506	*84.97*	*55.42*	*29.55*
	606	*84.96*	*53.91*	*31.05*
	706	*84.99*	*52.54*	*32.45*
	806	*85.03*	*51.34*	*33.69*
	906	*84.97*	*50.54*	*34.43*
	1006	*84.92*	*49.99*	*34.93*
	1106	*85.01*	*50.35*	*34.66*
	1206	*85.01*	*51.74*	*33.27*
	1306	*85.52*	*53.96*	*31.56*
	1406	*95.45*	*65.70*	*29.75*

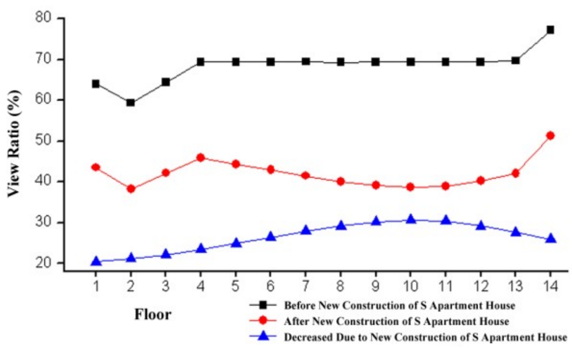


Figure 11 Comparison of view ratios on row 5

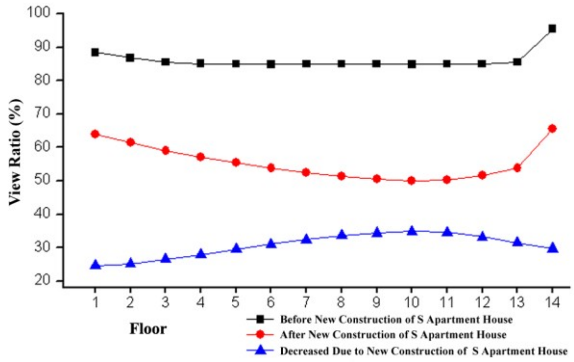


Figure 12 Comparison of view ratios on row 6

4.2.1. View Ratios of Row 5 of J Apartment Housing

The average view ratio of 14 houseunits on row 5 of building 105 of J Apartment House before new construction of S Apartment Housing was 68.48% and the average view ratio after new construction was 42.07%, so the decrease in view ratio due to new construction of S Apartment House was 26.41%. In the case of household No. 1005, the view ratio before new construction of S Apartment House showed 69.36%, but it was 38.71% after new construction, showing a decrease in view ratio of 30.65%, which was the largest decrease in view ratio of 14 floors. Because the new S Apartment House was built on the mid-slope of the mountain on the southeast of J Apartment House, the view ratios decreased more in the mid- and high-rise portions than the low-rise portion.

4.2.2. View Ratios of Row 6 of J Apartment House

The average view ratio of 14 households on row 6 of J Apartment House before new construction of S Apartment House is 88.20% and the average view ratio after new construction is 55.51%, with a decrease of 30.70% due to new construction of S Apartment House. For household No. 1006, the view ratio before new construction of S Apartment House showed 84.92%, but it decreased 34.93% to 49.99% after new construction, showing the greatest decrease in view ratio of 14 floors.

Photo 3 View picture of No. 606 of J Apartment House

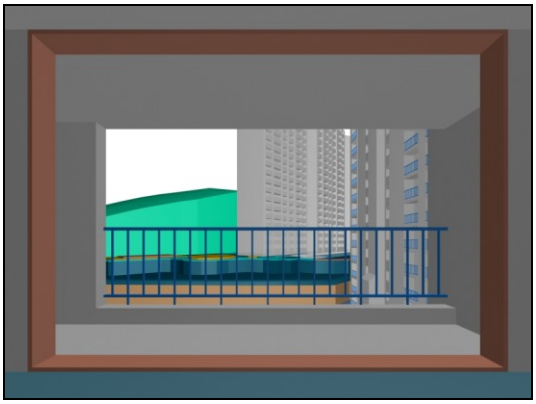


Figure 13 View image of No. 606 of J Apartment House

5. VALIDATION OF COMPUTER SIMULATION

To verify the validation of simulation results, the actual view photograph of the apartment house and the view photograph of the simulated image were compared. The program cannot be said to be usable for view evaluation unless the image of the view as seen by using the camera of Autodesk VIZ program is identical to the photograph actually taken on the same floor and same location.

Photo 3 is a picture taken at No. 606 of building 105 of J Apartment House to verify validity of the view evaluation. The structure of building 105 itself is seen on the left side and part of buildings 115 and 114 of S Apartment House are seen on the front. You can see the open cut section and the ridge of the hill on the left.

The image in Fig. 17 is a simulation of the view ratio as seen from the same place and at the same time of the picture-taking, to verify validity. Comparison between the view of the actual photograph and the view of the simulation image showed that the locations of S Apartment House and the ridge of the hill match each other.

6. CONCLUSION

An evaluation algorithm of the view night using graphic programs was presented and the followings are the results.

1) Design drawings such the layout, floor plan, elevation, sectional view of the building and the survey plan of the site are needed to make a simulation model for view evaluation, and the solid model function of AutoCAD was shown to be able to make a 3D model accurately for simulation.

2) The camera and render functions of Autodesk VIZ were shown to have high accuracy, and the 3D model for simulation proved capable of increasing the degree of understanding of view infringement by apartment household by visualizing the views before and after new construction in realistic images for actual view evaluation.

3) A program by which view ratios can be abstracted and calculated is required for accurate calculation of the view ratios of simulation images. Therefore, a view program was developed to calculate the view ratios and it was possible to improve calculation errors that may be generated from a manual calculation method and shorten the time required for calculation.

4) The results of analyzing the right of view showed that the average view ratio of 28 households on row 6 of building 105 of J Apartment House was 77.34% and the average view ratio after new construction was 48.79%. The view infringement ratios due to new construction of S Apartment House showed from maximum 30.65% to minimum 20.47% for row 5, and the view infringement ratios for row 6 were analyzed to be from maximum 34.93% to minimum 24.61% with the average view infringement ratio of 28.56%.

5) The simulated view images and actual photographs were compared based on the same floor and same location, and the result showed the view shape and location match each other.

6) Sunshine evaluation using 3D modeling verified accuracy in the view evaluation case of J Apartment House, and accurate view evaluation was found to be possible regardless of various shapes of building.

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LIGHTING IN THE NEW WORLD

Cristian Suvagau
BC Hydro, Vancouver

CFL: NOW OR NEVER!

Not so long time ago, in Ingineria Iluminatului #19, I was approaching the CFL topic with "The long way of CFLs to the American residential lighting". The topic was trying to explain the past failures of its technology, marketing and product distribution and point to the new opportunities to fully integrate CFLs in the conservative North American market. One year later, the realities of the world market (not just the American one) push to reopen the debate from another perspective.

Holding an obligation to make a great contribution to energy use reduction and global CO_2 goals, politicians from all over the world have focused their attention on incandescent lamp technology. From Australia, Japan, Europe to Canada and United States, governments are busy drafting regulations to restrict and potentially eliminate the use of the Edison's old commercial innovation. Advocates claim that replacing the worst-performing lamps with today's best available technology will reduce domestic energy consumption for lighting by 60% in the EU alone, equivalent to saving 30 million tons of CO_2 pollution every year.

The high energy filament bulbs are simply being phased out in order to improve energy efficiency and meet climate change targets. Since the first drafts of legislations (2006 and 2007) that were purely banning the incandescent lamp, the present regulations (as the one just voted by the EU energy ministers in October 2008) are targeting minimum lamp efficacy (lumen per watt) to eliminate energy inefficient lighting products. Most noted (and due to persisting lobby for the lighting industry) the phasing out will be instated in steps, starting from 15 lm/W-20 lm/W (Australia, Canada, EU) and anywhere from 2008 (Australia, EU) to 2012 (Canada, US, Japan), and poised to reach even 45 lm/W in 2020 (US). The metrics are not simple and do also involve a staged ban on certain "lumen-bins" (popular incandescent wattages used in residential and commercial markets like the 60 W and 75 W). Since the incandescent lamps (including halogen) have an efficacy of anywhere from 10 to 14 lm/W, this technology is virtually doomed of existence pretty soon. Some last forts of the incandescent technology will be with reflector and specialty bulbs. Even only little legislation (Japan so far) indicate the CFL as the natural heir for screw-in (commodity market) applications, it is not hard to do the math. With luminous efficacies between 40 lm/W and 60 lm/W, and considering the still long way to the commodity market of the LEDs, CFLs could be here to stay. However, the move seems to be controversial.

The sudden demise of an established technology (130's anniversary in 2009) combined with a resistance to everything "imposed by law" is sparkling vivid debates with the public, mostly in conservatives markets like the North American ones. From health issues to environment disposal hazards and ending with costs, CFLs are in the middle of a man-made, media storm that has to be navigated with caution.

Market Reality

In 2008 the CFL market penetration in North America was about 25% of the incandescent lamp continuing a strong up-swing momentum since 2005. If the trend continues like this, and with help from regulations, we can see complete market transformation by 2020. However, the supply of CFLs resides mainly in China.

Since 1998, China has become the world's largest producer and exporter of the energy-saving lamps, changing the structure of a global market that was once monopolized by European and American companies such as Philips, GE, and Osram. Chinese manufacturers supplied close to 1 billion CFLs worldwide in 2004, or about 75% of the global total (according to Global Source's report Light Bulbs & Tubes). In the face of intense international competition, the low price of the Chinese-made bulbs has been the leading factor behind this growth. Meanwhile, faced with relative and (often) mediocre quality, both European and North American legislators have tightened the quality control and import technical criteria. From over 4000 CFL factories existing in China in the early 2000, half have survived with a relative good constant offer.

Despite this dramatic market supply correction, and faced now with the golden opportunity to supply most of the world lighting commodity market, Chinese suppliers indicated that supply is not an issue. For example, the CEO of TCP (a large CFL manufacturer in China supplying the North America market) recently indicated that currently they can produce 1 billion CFLs in a year and they could ram up their production capacity in 3 to 4 months and produce 2 billion CFLs.

Cost is somehow another issue. Even if CFLs sell in Canada and US with as low as \$2, they are still more expensive than the regular \$0.5 for equivalent incandescent lamps. Often, consumers have also to support the cost of having to adapt fittings for the new CFL bulbs. Although CFLs will last way longer (up to 10 times), cost less in energy (only about 20%), regular consumers do not do the life-cycle cost accounting, being mostly concerned about the high initial investment.

The main problem is the cost of manufacture, which is, on average, about 20 times higher for a CFL than an incandescent. With improvements in manufacturing processes, prices have been falling for CFL, but the difference in pricing between the traditional forms of lighting and CFL is still quite significant.

In this innovation-driven market, new advances in manufacturing technology are rapidly lowering costs. At present, however, the only way to get customers to purchase the much more expensive CFL is to decrease the price for consumers - either through subsidies or tax incentives or by selling CFL at lower prices initially and (eventually) gradually raising the price over time as more people make the switch.

Health/ Safety

- **Radio Frequency Interaction/ Flickering**. There are lots of anecdotal reports of headaches and other health issues associated with CFLs. Industry's responses are based on commonly accepted claims that headaches associated with fluorescent lighting are due to the flicker associated with line frequency operation. A portion of the population (25% to 30 % by some estimates) is sensitive to that flicker. The high-frequency electronic ballasts widely used in today's CFLs eliminate most of that flicker. To-date studies don't prove that CFLs don't cause headaches (it's hard to prove a negative) but they do indicate that people generally do better under fluorescent lighting with high-frequency ballasts. Interference to televisions, radios, wireless, telephones, and remote controls is also possible, as labelled on most of the CFL products.
- **Harmful UV radiations.** All fluorescent lamps emit some UV. Typical fluorescent lamps, including CFLs, which consumers would encounter, emit very low (negligible) levels of UV. Both CIE and IESNA have published standards relating to radiation emissions from general purpose lighting. In US, if a CFL were to exceed allowable levels of UV (according to IESNA RP 27.3), its packaging would be required to be labelled with a caution label. This standard, which was developed with the assistance of the federal health board, requires lamp manufacturers to provide a suitable caution if one is needed.

Environmental Concerns

Compact bulbs contain a drop of mercury (less than 5mg) and although do not pose health hazards when in use, they should be considered dangerous waste at the end of their useful life. The bulbs sold in Europe bear a pictogram indicating that the lamp should not be thrown away in the usual garbage bin but must be returned to the store and recycled. However, in Canada and United States fluorescent lamps with 5 mg or less of mercury are eligible for an exemption, due to their usefulness for energy savings and a lack of functional alternatives. Canada has a standard in place to reduce the amount of mercury in lamps by 80% from 1990 baseline levels by 2010 and the United States aims to increase fluorescent lamp recycling rates to 80% by 2009.

Mercury emissions to the atmosphere (from the disposal treatments) continue to be an environmental concern. Emissions can be reduced further through safeguards against mercury losses from lamp breakage during transport, such as plastic sheathing or other effective end-of-life packaging.

Technology Limitations

The CFL bulbs actually found in the market are plagued with several shortcomings:

- They are not suitable for use in the cold climates (most of Canada and Northern US)
- They should not be used in a totally enclosed recessed fixture due to heat accumulation that could shorten the life of the electronic components.
- The lamps cannot be connected to standard dimmers.

- There is a short delay between the turn on moment and full intensity operation (soft start)
- Frequent on-off switching (i.e. when operated by occupancy sensors/timers) could dramatically shorten the CFLs life time.
- The intensity of the output light gradually decreases with aging.
- There are concerns about their real lifetime and about some catastrophic failure modes.
- Most of the CFL ballast have power factors less than 0.5 and could cause disruptive harmonics and may cost electrical utilities extra demand.
- Esthetical issues are not un-common since few CFLs have the all accepted incandescent bulb shape.

Conclusion

Manufacturers will certainly be able to address and correct some of the problems listed here. Regulatory agencies should develop and enforce more stringent standards addressing safety, harmonics proliferation concerns and, finally, governments, both federal and provincial, should ensure that effective recycling networks are developed and that appropriate incentives are in place. Failing to do so, incandescent replacement could be compromised or more focus can be drawn to other alternatives, however harder in tight economic times. On a news note, GE just announced that has cancelled the development of a maverick incandescent technology that could reach efficacies of 30-40 lm/W, only two years after their well mediated start of a visionary research plan. Bearing the costs of all these improvements, CFL could remain the most viable alternative (considering cold cathode sources still a compact fluorescent technology) to the (soon to be extinct) incandescent lamp. Nevertheless, as the world does not stay still, LEDs are developing faster and put a serious treat to the CFL market. However, since LEDs are utterly expensive and they propose a different lighting paradigm (with solid state luminaires rather than replaceable lamps), CFLs could still enjoy a long and happy life.

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