Aalborg Universitet

Energy Savings by Individual Dynamic Lighting Control

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Annex 45
Energy Efficient Electric Lighting for Buildings

Biannual Newsletter

1/2008

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

Annex website:
lightinglab.fi/IEAAnnex45

New Doctors in the Lighting Field

M.Sc. Meri Viikari defended her Doctoral Thesis *Analysis of the Existing Visual Performance Based Mesopic Models and a Proposal for a Model for the Basis of Mesopic Photometry* at Helsinki University of Technology, Finland in December 2007.

David Lindelöf defended his Doctoral Thesis *Bayesian Optimisation of Visual Comfort* at Ecole Polytechnique Fédérale de Lausanne, Switzerland.

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building performance congress

Improving Energy Efficiency in Commerical Buildings Conference

During the Light+Building Fair April 2008 Building Performance Congress was held in Frankfurt Germany. The themes of the congress were Light Focus, Energy Focus and IEECB Focus (Improving Energy Efficiency in Commercial Buildings). The topics in the IEECB Focus were Policies, HVAC, Behaviour and investor motivation, Monitoring, Energy performance of buildings directive, Lighting, Programmes and energy services, Implementation, monitoring and building energy managements systems and Data Centres and IT equipment.

Continued on page 2.

Solid State Lighting Luminaires

U.S. Department of Energy has finalized a new ENERGY STAR specification for solid-state lighting luminaires. The criteria will go into effect on September 30, 2008. More info http://www. energystar.gov/ index.cfm?c=new_specs.ssl_luminaires.

Join the lighting revolution! NOW!

Marc Fontoynont

Demand for Lighting Electricity Still Grows Worldwide...

Demand for lighting electricity is still growing, 1.8% in OECD countries and 3.6 % in the rest of the world, although energy saving lamps such as CFL are starting to take a significant part of the home market. This demonstrates that in today's model, lighting electricity consumption is linked to the general development of our economies, and that the penetration of energy saving alternatives is progressing more slowly. The general trend is still to increase light levels in buildings and in streets, mainly in countries with strong economic development. Often, this is conducted with poor understanding of the fundamental requirements of humans regarding light exposure.

A Large Fraction of Our Lighting Electricity Is Wasted

Most of the energy saving potential appears, at first glance, to be related to the large-scale substitution of tungsten-halogen lamps by lamps with luminous efficacy above 50 lm/W (CFLs and LEDs today) instead of 15 lm/W. The other major potential stands in the careful management of the power of lamps to deliver just the right luminous flux, at the right time, in order to reduce the lighting energy waste.

Turning light off any time they are not needed has quite a high potential for buildings using light at daytime. Turning lights off when buildings are not used or when daylight is sufficient can lead to savings in the range of 25 to 50 % depending on the quality of daylight in buildings. Today, simple control strategies are available, either centralized or individually attached to the luminaries

Designing buildings for the right amount of daylight penetration, and the use of efficient sunshades should lead to minimizing the drawback of overheating associated with excessive daylight penetrations.

New Findings Demonstrate That We May not Need so Much Light!

However, findings dealing with research of human preferences and visual performance clearly identified directions for lighting practice which would allow to stop the growth of lighting electricity demand, and possibly initiate a strong reduction of the required light fluxes from lamps.

It was found that optimal solutions are not to provide high and uniform illuminance inside our buildings, but high illuminances on task, appropriate luminances on vertical surfaces, with special modulation, and significant reduction of glare (light sources should be hidden from the field of view). Solutions have been found which use 40% less electric power with this approach, in comparison with standard practice.

Furthermore, findings in medical science reveal that light plays important roles in maintaining optimum regulation of biological rhythms and hormones on a daily basis (International Lighting Commission, www.cie.co.at). It is therefore essential that the professionals of the lighting field develop lighting strategies improving health and well-being of building occupants, and select the most adapted energy-efficient light sources.

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Annex 45
Energy Efficient Electric Lighting for Buildings

Management of the Annex

The Executive Committee of the Energy Conservation in Buildings and Community Systems (ECBCS) programme established a new research project (Annex) in June 2004, called Energy Efficient Electric Lighting for Buildings. Professor Liisa Halonen from the Lighting Laboratory of Helsinki University of Technology was elected as the Operating Agent of Annex 45.

Operating Agent:	**Finland, Helsinki University of Technology** **Professor Liisa Halonen**
Subtask A Leader:	**France, École Nationale des Travaux Publics de l'État** **Professor Marc Fontoynont**
Subtask B Leader:	**Austria, Bartenbach LichtLabor GmbH** **General Manager Wilfried Pohl**
Subtask C Leader:	**France, Centre Scientifique et Technique du Batiment** **Mireille Jandon and Nicolas Couillaud**
Subtask D Leader:	**Finland, Helsinki University of Technology** **D.Sc. Eino Tetri**

Objectives

Identify and accelerate the use of energy efficient high-quality lighting technologies and their integration with other building systems

Assess and document the technical performance of existing and future lighting technologies

Assess and document barriers to the adoption of energy efficient technologies and propose means to surmount these barriers

Annex website:
lightinglab.fi/IEAAnnex45

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Improving Energy Efficiency in Commercial Buildings

In the lighting Session the following presentations were given:

Power density targets for efficient lighting: Practical examples, W. Ryckaert. KaHo, Sint-Lieven; Light and Lighting Laboratory, Belgium

Concepts and techniques for energy efficient lighting solutions, E. Tetri, Helsinki University of Technology, Finland & W. Pohl, Bartenbach LichtLabor, Austria

The use of high dynamic range luminance mapping in the assessment, understanding and defining of visual issues in post occupancy building assessments, S. Coyne, Light Naturally, Australia

Integral approach to design building engineering systems: (lighting, heating, air- conditioning) - as an effective way to Energy Saving, J. Aizenberg, VNISI, Journals Svetotekhnika and Light and Engineering, Russia

Improvement of the energy efficiency of a distribution warehouse in Madrid (Spain) with special emphasis on daylight optimisation, J. C. Bruno, Universidad Rovira i Virgili, Spanien

Market development of ESCO schemes for lighting refurbishment, M. Zumbusch, Berliner Energieagentur GmbH, Germany.

In the paper *Non-residential buildings for mitigating climate change: Summary of the findings of the intergovernmental panel on climate change* by D. Ürge-Vorsatz, A. Novikova and M.D. Levine, presented by P. Bertoldi CO_2 reduction potential for buildings in 2020 and review of measures were listed. Findings were based on approximately 80 recent studies from 36 countries. Countries were divided in three country groups: Developed countries, Economics in transition, Developing countries.

When considering measures covering the largest potential for CO_2 reduction efficient lighting was on third position in the Developed countries (after shell retrofit, including insulation, especially windows and walls and space heating systems) second in Economics on transition (after pre- and post insulation and replacement of building components, esp. windows) and first in Developing countries. When considering measures providing the cheapest mitigation options efficient lighting was on third position in Developed countries after appliances and water heating equipment and on first position both in Economics on transition and on Developing countries.

Wouter Ryckaert set power density targets for efficient lighting in his paper. The normalised power density NPD [W/m² 100 lx) can be written as

$$NPD = \frac{P_{sys}}{\Phi_{TA}^{fin}} = \frac{100}{MF \cdot U \cdot LOR \cdot \eta_{lamp} \cdot \eta_{gear}}$$

The target values for the different quantities are

- Efficiency of the gear η_{gear} > 0,85
- Efficacy of the light source η_{lamp} > 70 lm/W
- Efficiency of the luminaire (light output ratio) LOR > 0,75
- Utilance, i.e. the efficiency of directing the luminous flux from the luminaire to the task area U; where A_{nTA} and A_{TA} are the total non-task areas and total task-areas.

$$U > \frac{2}{1 + 0.5 \cdot (\frac{A_{nTA}}{A_{TA}})}$$

- Maintenance Factor MF > 0,75.

From the equations above the target value for the installed power can be derived, were Φ_{TA}^{fin} is the maintained luminous flux on the task area.

$$P_{sys} < \Phi_{TA}^{fin}(100lm) \cdot (1.5 + 0.75\frac{A_{nTA}}{A_{TA}}) \quad [W]$$

Sample Survey on Indoor Lighting Needs and Consumption in Italy Tertiary Sector

Maria Alabiso & Walter Grattieri

Background

The Tertiary sector shows in Italy a remarkable dynamics that, in terms of electricity consumption, involves growth rates double than the average. For the sector indoor lighting represents a significant component of the overall consumption and justifies thorough analyses aimed at evaluating in what way and to what extent energy saving measures can be implemented. To this purpose an enquiry was carried out across a sample of buildings that allowed determining the number of lamps installed, their characteristics, the typical operating usage, and the electricity demand. This information, complemented by a feasibility study on the possible technological improvements, represent the basic requirements needed to individuate cost/effective measures able to produce significant savings in a selected type of buildings.

The Tertiary Sector

The Tertiary sector encompasses very diversified economic activities ranging from small businesses to large distribution, from hotels to hospitals, including not-for-sale services offered by the public administration. In 2006 it recorded an electricity demand equal to 88.3 TWh, which corresponds to 27.8 % of the national consumption. Almost 26% of the sector's consumption is due to commercial activities (large distribution, supermarkets, shops, etc.), that joined to hotels/restaurants and other businesses represent about 60% of the total. By all means, a remarkable share of said consumption is needed for both outdoor and indoor lighting. However, with the only exception of public lighting data (6.4 TWh in 2006), the official statistics don't report any peculiar information on lighting consumption and little is known in Italy that allows to reliably decompose the aggregated consumption into its end-use components.

Sample Survey

In 2004 an investigation was carried out in the Tertiary sector in Italy that allowed determining, the main features of the energy end-uses for electricity, natural gas, and fuel oil. The survey was based on face-to-face energy audits across a sample of 140 users. Most users were found in the Commerce and Hotels and Restaurants branches, with respectively 23.6% and 16.4% of the total. Figure 1 shows the overall result of the audits for the electricity, the break down of consumptions highlights the relevance of indoor lighting (21% of the total), whose consumption is second only to HVAC (29%).

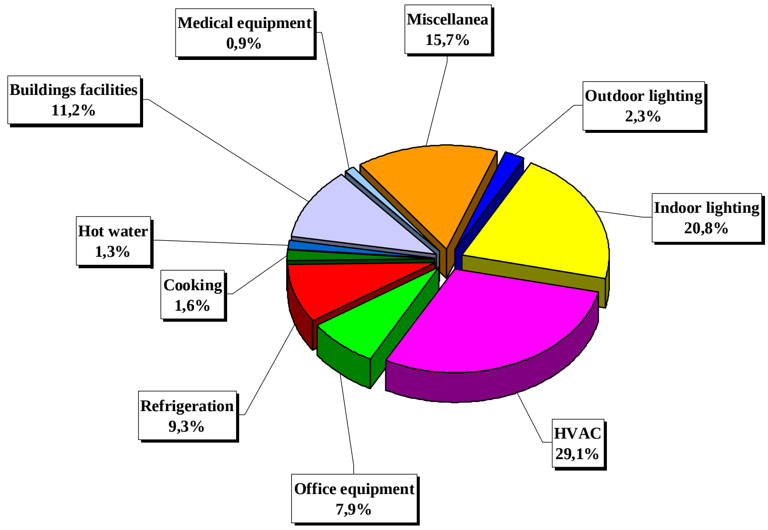

Figure 1: Break down of electricity consumption in the sample (140 users)

The survey identified about 100,000 light sources, Figure 2, most of them represented by linear fluorescent lamps (roughly 2/3 of the total) and by compact fluorescent, halogen and incandescent lamps (about 8 % each).

If we leave apart the group of Metal Halide lamps installed at some exposition sites included in the sample, all remaining lamp types have little significance for the sector. It is also interesting to observe the linear fluorescent, besides being the most common type of lamp, is also the most evenly distributed across the sample.

The compact florescent one is particularly common in Real Estate and Public Administration, and most of incandescence and halogen lamps can be found in Hotels and Restaurants.

In premises and applications with high operation times, LED type lamps are chosen for their duration that minimizes maintenance interventions.

As for the specific consumption, the Supermarkets, with 67 kWh/yr/m^2, result the most demanding users, followed by the Hospitals, with almost 58 kWh/yr/m^2.

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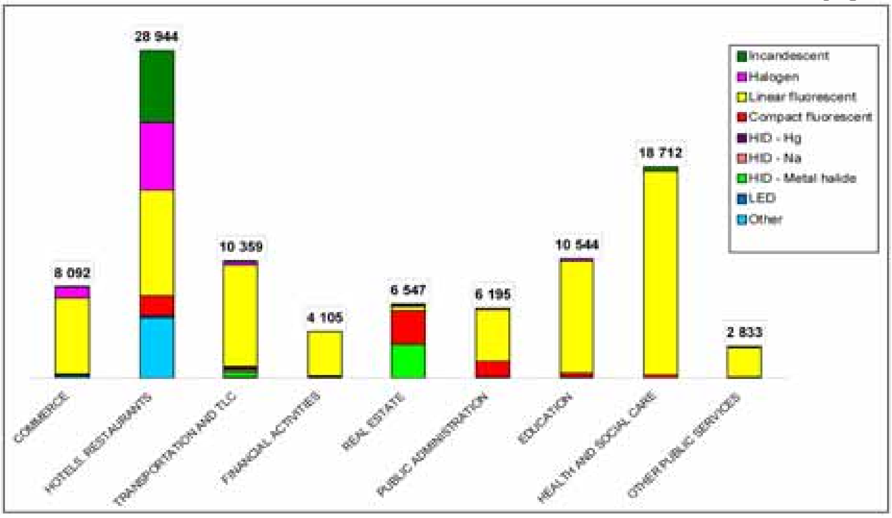


Figure 2: Distribution of lamps across the sample (140 users)

New Doctors in the Lighting Field

Analysis of the Existing Visual Performance Based Mesopic Models and a Proposal for a Model for the Basis of Mesopic Photometry

Meri Viikari

Meri Viikari on a depate with the horouned opponent Dr Mike Pointer.

The work started with investigation of the origins of the photopic spectral luminous efficiency function V(λ). The ability of the existing photopic spectral luminous efficiency functions V(λ), V_M(λ), or V_{10}(λ) to describe peripheral photopic vision was examined. A new photopic spectral luminous efficiency function for peripheral vision V_{per}(λ) was proposed for the photopic end with which the mesopic photometric model should merge at the upper luminance limit of the mesopic region.

The existing mesopic photometric systems were reviewed. The two recently proposed mesopic models, MOVE-model by the MOVE consortium and the X-model by Rea et al, are based on visual task performance. Performance based mesopic models are claimed to preserve additivity within the given light level. The two performance based models are currently being analyzed by the CIE TC 1-58 in order to result in an internationally agreed system for performance based mesopic photometry.

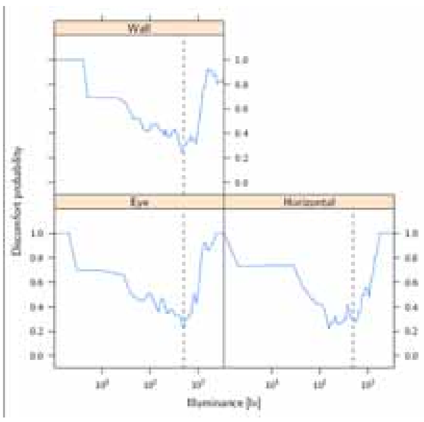
The work continued to generate contrast threshold and reaction time data in order to compare the existing performance based mesopic models. The differences between the mesopic luminances predicted by the two models were evident. The work concluded by proposing a new performance based mesopic model. The new model is based on the same experimental data as the MOVE-model. The modified MOVE-model was compared along with the other two performance based models using three independent experimental visual performance data sets. The comparison indicated that the modified MOVE-model described the experimental data best.

Information on mesopic photometry can be found from the website of CIE Technical Committee TC 1-58 Visual Performance in the Mesopic Range. On the website there is also a tool for calculation of mesopic luminance with the MOVE-model. http://www.lightinglab.fi/CIETC1-58/move.html. The dissertation can be found at http://lib.tkk.fi/Diss/2007/isbn9789512291229/

Bayesian Optimisation of Visual Comfort

David Lindelöf

We propose a self-commissioning, user-adaptive blinds and electric lighting controller for small office rooms. Self-commissioning, in this context, means that the controller builds an internal representation of the room, in particular of the room's daylighting characteristics, automatically and without user input. By user-adaptive, we mean that the illuminances the controller will seek to maintain are derived from a statistical analysis of the user's behaviour on the manually overridable blinds and electric lighting.



Self-commission and user-adaptation are implemented by two decoupled software elements. The first element is a method for modeling the daylighting illuminance on arbitrary locations in the office room, when the windows are shaded by one or two venetian blinds. It uses the past history of illuminance distributions in the office room for a similar scene configuration, and models the current illuminance on a given point as a linear combination of outdoor global and diffuse irradiance.

The second element is an algorithm for the estimation of the user's visual discomfort probability. It is a function of the current illuminance distribution in that office room, and of the past history of the user's interactions with the blinds' and lighting controls. A bayesian formalism is applied to infer the probability that any illuminance distribution should be considered by the user as visually uncomfortable.

We describe how these elements have been integrated in a blinds and electric lighting controller on an office room of the experimental LESO building and we present the results of the algorithm's adaptation to the preferences of that room's user.

We have also assessed that controller's performance on computer-simulated virtual office rooms. We have let the controller run for one year simulated time on six different combinations of office room location (Rome and Brussels) and orientation (north, west and south). These simulations have let us evaluate the energy savings made possible with such a controller, and the improvement of the user's visual comfort.

The dissertation can be found at http://leso.epfl.ch/e/education_phd.html

Energy Savings by Individual Dynamic Lighting Control

Ásta Logadóttir & Jens Christoffersen

This project aims to identify an acceptable approach of dynamic lighting control for office environment in Denmark with focus on user acceptance and energy efficiency. This is done by, exploring user preferences for the dynamic lighting concept in a simulated office environment with daylight contribution. The results presented here represent the use of the dynamic lighting concept during winter months in Denmark.

Method

The experiment was conducted in the Danish Building Research Institutes (DBRI) Daylight laboratory. Inside the laboratory there are two identical, side-by-side experimental rooms, one room for subjects (room A) and the other for measuring equipment (room B). The façade faced 7° from true south and the glass area covered 44% of the façade.

The lighting system consisted of 3 Philips Savio luminaires (266 x 1259mm ceiling-mounted direct) in each room. Each luminaire contained 3 lamps; two were 6500 K and one 2700 K. The lamps operated on electronic dimming ballasts by a commercial lighting control system. To adjust the lighting conditions, the subjects used a remote control box placed on the desk in room A.

The maximum desktop illuminance from electric lighting was 1270 lux, and the minimum was 57 lux. The correlated colour temperature (CCT) was measured at a 45° viewing angle from the window at eye-level of a seated person (1.2m above the floor). The CCT from electric lighting could be adjusted between 2900 K and 5500 K.

Measurements

The experiment was carried out within the timeframe of December 20, 2006 to March 19, 2007. There were 50 subjects (24 male, 26 female), mostly students, with age ranging from 20 to 35. Subjects brought their own work with them which included typical office tasks, such as reading, writing and /or working on a computer.

The subjects spent one working day in the laboratory, they were prompted to adjust the lighting conditions every half an hour and answer questionnaires. Illuminance levels were measured every 30 seconds outside as well as in various places in the two rooms.

The lighting energy use, luminance and CCT were recorded 23 times during the day just before and after subjects changed the light setting by the remote control box.

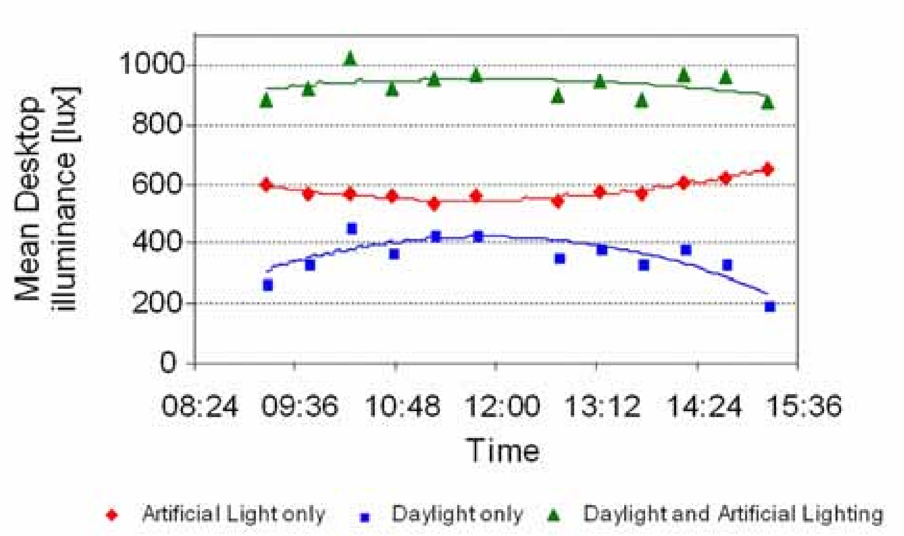


Figure 1. Mean desktop illuminances for all subjects during hours of the day.

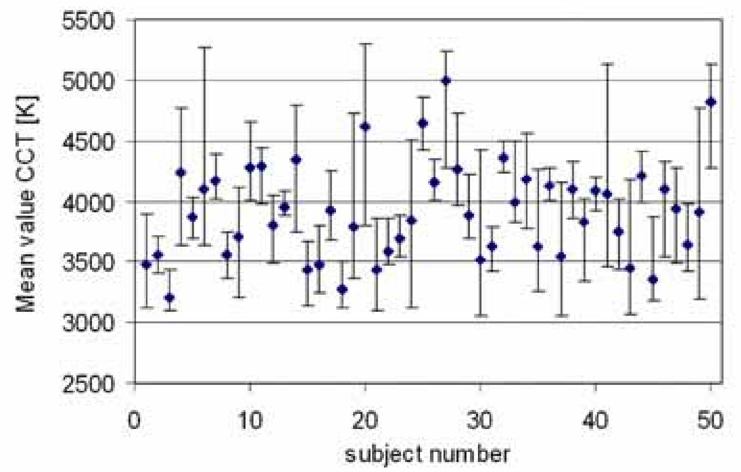


Figure 2. Mean value chosen pr. day by every subject (diamond) from electric lighting with the upper and lower 95% confidence interval.

Results

Total desktop illuminance (daylight and electric lighting) had a mean value of M=926 lux (SD= 538 lux), where electric lighting contributed with M = 577 lux (SD=272 lux). The data for electric lighting shows tendency in reduced output by increased daylight contribution (middle of the day). However this tendency did not result in a preferred light level during the day.

CCT for daylight and electric lighting had a mean value of 4543K (SD= 449K) and the electric lighting had a mean CCT value of 3917K (SD=494K). The mean CCT value for the combination of daylight and electric lighting is fairly stable throughout the day but there was substantial variation between the subjects. In the experiment, CCT measurements varied between 3086 and 6325K (daylight and electric lighting), but almost half of the subjects chose the CCT level to be between 4300 and 4900 K. In the experiment, measurements varied between 2955 and 5350 K for electric lighting and 66% of the chosen values lie in the interval between 3400 and 4300 K.

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Energy Savings by Individual Dynamic Lighting Control

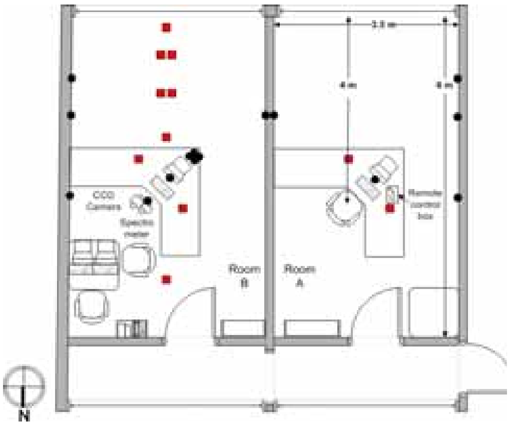

Figure 3. DBRI's Daylight laboratory. Room A used by subjects, Room B used for measurements and researcher. Black circles imply a vertical illuminance meter and red squares imply a horizontal illuminance meter.

The lighting system energy use pr. square meter could vary between 4.8W/m2 and 26.2W/m2. For this setup the total energy use pr. square meter was M = 12.5W/m2 while a constant level of 500 lux from electric lighting on the desktop cause the energy use pr. square meter to be 11.2W/m2.

The questionnaire data implies that subjects were generally satisfied with the lighting conditions as a whole in the experiment. Most of the subjects registered to have controlled the lighting depending on daylight condition and task. It was valued important to be able to adjust the light level as well as the colour of the light. The subjects found it highly acceptable if the electric lighting was automatically controlled, with the opportunity of manual override.

Further research will be conducted in attempt to achieve energy efficiency in combination to user satisfaction and preferences by performing measurements during different seasons, different desk placements in the room and adding a desk lamp.

This project is financed by ELFORSK-project 338-035 Energy Savings by Individual Dynamical Lighting Control.

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Join the lighting revolution! NOW!

Innovative Energy Efficient Light Sources Are Now Available, But Quality Control is Insufficient

Quality control of light sources in still insufficient, mainly for new energy saving products. There is still a large discrepancy between CFL products There are still CFLs which are showing slow increase of flux after start, poor colour rendering, short lamp life and ballasts with poor performance (reactive power). LEDs can stand the same type of criticism, with also possible excess of glare if optics are not appropriate. It is essential to boost confidence of consumers regarding the quality of energy efficient light sources.

2008: The Year To Launch Key Actions

The world energy context forces us to act rapidly, and to define actions.

Phase-out of tungsten-halogen lamps: On the European markets, we estimate that there are about 200 types of tungsten halogen light sources, and that there is the possibility to replace today about 50 models by energy efficient light sources (thus dividing the electric power by a factor of 3 or more. This phasing out has to be organized with a clear road-map, defining the progressive substitution of tungsten-halogen source over time

In parallel, quality control of light sources is essential, to boost consumer confidence, and possibly to take the opportunity to improve lighting conditions.

More research of the fundamental needs of humans regarding light is essential, since this will lead to lamps and lighting strategies better adapted to the needs.

International standards have to be adjusted, stressing the fundamentals of lighting requirements, and proposing energy-efficient scenarios. Maximization of Daylight use in one of them.

Analysis the global environmental impact of light sources (during the production, and after use, through recycling) is essential, to select the best technologies

Existing bodies such as the International Lighting Commisison can handle coordination of research on the fundamentals of human requirements and update of recommendations.

But National Energy Agencies must also coordinate their policies, since the lighting industry is part of the world economy, and the problem of lighting efficacy is a world issue.

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Continued on page 3.

Sample Survey on Indoor Lighting Needs and Consumption in Italy Tertiary Sector

Energy Efficiency in Lighting

According to the survey outcome, energy efficiency in lighting can be retained as most cost/effective when applied to a restricted group of consumption categories, such as: Supermarkets, Hotels, Banks, Offices, Schools and Hospitals.

Due to their peculiarities, these users can both maximize the energy savings expected and benefit from the tax credits presently foreseen by the Italian legislation on energy efficiency support. Among said users, the Hotels qualify for the contextual implementation of two sets of measures, namely: "*Upgrade of fluorescent tubes by replacing the magnetic ballasts with electronic ones*" and "*Replacement of incandescent lamps with CFL*".

Potential savings are estimated to be of the order of 5 % in the first case and 19 % in the second.

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International Workshop and 7th Annex 45 Expert Meeting

Visual Quality and Energy Efficiency in Indoor Lighting: Today for Tomorrow

31 March - 2 April 2008, Rome, Italy

The Annex 45 7th Expert Meeting was opened by the International Workshop “Visual Quality and Energy Efficiency in Indoor Lighting: Today for Tomorrow”, hosted by the Faculty of Architecture “L. Quaroni”, SAPIENZA University of Rome, sponsored by ASSIL – Italy and ISES.

In line with Annex 45, whose objectives are to identify and accelerate the use of energy efficient high-quality lighting technologies and their integration with other building systems, to assess and document the technical performance of existing and future lighting technologies, to assess and document barriers preventing the adoption of energy efficient technologies and propose means to resolve these barriers, the topics of the workshop were energy efficiency, visual quality, technological news and perspectives, integration between natural and artificial lighting, light and health, and case studies.

The workshop, organized in the framework of the periodical meetings of the Annex, has been an occasion for a fruitful exchange of ideas at international level, with a special focus on the Italian situation. The attendance exceeded 70 people, and most of the participants came from the universities, the industry, the Ministry of the Environment, and other institutional (national and international) organisations. Several countries were represented, from China to USA, from Singapore to most of the European countries.

In the workshop, the work of the Annex 45 was presented by the Operating Agent Prof. Liisa Halonen, while many presentations focused on the launching of LED technology, as it is one of the major tools to reduce electricity consumption related to lighting, and on efficient solutions to integrate natural and artificial light to save energy and improve visual quality in buildings.

The seventh Expert Meeting of Annex 45 was on 31 March – 2 April 2008 in Rome, Italy. The meeting was hosted by Fabio Bisegna, University "La Sapienza", Dept. Fisica Tecnica and Simonetta Fumagalli, ENEA. There were 23 participants from 10 countries.

FONTANA DI TREVI
In 1732, Pope Clement XII commissioned Nicola Salvi to create a large fountain at the Trevi Square. The Trevi fountain is at the ending part of the Aqua Virgo, an aqueduct constructed in 19 BC. It brings water all the way from the Salone Springs (20 km from Rome) and supplies the fountains in the historic center of Rome with water.
The fountain is not only celebrated for its excellent water but for the legend that whoever drinks it or throws a coin in the fountain, will assure his return to Rome.

Want more info? Contact your country representatives or Operating Agent!

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Annex 45 Expert meetings

8th Expert meeting
17 - 18 June 2008
Delft, The Netherlands
Truus de Bruin-Hordijk TU Delft

9th Expert meeting
15 - 17 October 2008
Malmö, Sweden
Nils Svendenius, Lund University
Peter Pertola, WSP Ljusdesign

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme