

Chapter 8: Lighting design and survey on lighting today and in the future

Topics covered

8	Lighting design and survey on lighting today and in the future	205
8.1	Thoughts on lighting design	205
8.2	A technological approach	208
8.3	The role of LEDs	209
8.4	Architectural view on illuminants	210
8.5	Energy efficient lighting culture	211
8.6	Survey on the opinion of lighting professional on lighting today and in the future .	211
8.6.1	Introduction	211
8.6.2	Results	212
8.6.3	Summary and discussion	225
	References	227

8 Lighting design and survey on lighting today and in the future

8.1 Thoughts on lighting design

“Primarily, it is light which brings materials to life and gives a room its form. A single beam of light allows for a surface to express itself and creates shadows behind objects”, states Tadao Ando, one of the most famous architects of light.

life and gives a room its form. A single beam of light allows for a surface to express itself and creates shadows behind objects”, states Tadao Ando,

Lighting design is more than the planning of stipulated light intensities and luminance levels. Lighting design is also more than the fulfillment of physiological visual requirements of visual perception. The fulfillment of these requirements belongs to the necessary prerequisites of illumination. Lighting design is more than just the fulfillment of normative guidelines. Lighting design means the creation of an appearance (e.g. of a room), which complies not only with the technical requirements but also with the emotional and aesthetic requirements of the user.

ated light intensities and luminance levels. Lighting design is also more than the fulfillment of physiological visual requirements of visual perception. The fulfillment of these requirements belongs to the necessary prerequisites of illumination. Lighting design is more than just the fulfillment of normative guidelines. Lighting design means the creation of an appearance (e.g. of a room), which complies not only with the technical requirements but also with the emotional and aesthetic requirements of the user.

Designing with light is based on psychological perception correlations, which cannot be measured quantitatively (at least at present), and therefore cannot be mathematically described or converted. Lighting solutions, in the sense of creations in light, are very difficult to represent and communicate as they are abstract and can practically only be perceived by means of visual perception (one has to be able to see the solution). In order to be able to convey an illumination solution, they are either graphically represented (artwork) with the help of computers simulations (renderings), or represented by scale models. Ultimately, these are just aids and the true effects can only be experienced in a situation.

ption correlations, which cannot be measured quantitatively (at least at present), and therefore cannot be mathematically described or converted. Lighting solutions, in the sense of creations in light, are very difficult to represent and communicate as they are abstract and can practically only be perceived by means of visual perception (one has to be able to see the solution). In order to be able to convey an illumination solution, they are either graphically represented (artwork) with the help of computers simulations (renderings), or represented by scale models. Ultimately, these are just aids and the true effects can only be experienced in a situation.

From an architectural point of view lighting is a means to express and underline the desired character of the building space, which may be defined by a general design style of the architect.

ean to express and underline the desired character of the building space, which may be defined by a general design style of the architect.

Different places need different ways of lighting design. Anyway, it is possible to identify three main typologies of environments, each one characterised by different hierarchies of objectives, with a specific technical, functional or aesthetic priority:

sign. Anyway, it is possible to identify three main typologies of environments, each one characterised by different hierarchies of objectives, with a specific technical, functional or aesthetic priority:

- a. Environments designed for work and service to the public: places where the functionality is the key element guiding the work of the designer, and the main aspects to satisfy are the rules of the vision and ergonomics, the safety and the communication
- b. Environments designed for exhibitions and sales: places where the most important need is the image, be it faithful to the truth or distant to the reality, virtual, fascinating
- c. Environments designed for residence and tourism: places where light should satisfy the need for comfort, relaxation, aesthetic value, status symbol

Visual perception is first of all a mental procedure, and not only a pure sensation (like e.g. a thermal sensation, which causes feelings of coldness or warmth). It is a means to receive information about our surroundings, about the distances, surfaces, textures, about what happens around us, and all this information arouses emotions. Our perception is very selective, prejudiced by our personal experience, and is influenced also by our actual mental state, history and expectations.

e, and not only a pure sensation (like e.g. a thermal sensation, which causes feelings of coldness or warmth). It is a means to receive information about our surroundings, about the distances, surfaces, textures, about what happens around us, and all this information arouses emotions. Our perception is very selective, prejudiced by our personal experience, and is influenced also by our actual mental state, history and expectations.

Through the visual perception system we receive the largest amount of information (most of it unconsciously) about our environment. Optical illusions are very popular to demonstrate this perception procedure: we interpret (unconsciously) and not controllably) by a mental process what we are seeing (see Figure 8-1).

largest amount of information (most of it unconsciously) about our environment. Optical illusions are very popular to demonstrate this perception procedure: we interpret (unconsciously) and not controllably) by a mental process what we are seeing (see Figure 8-1).

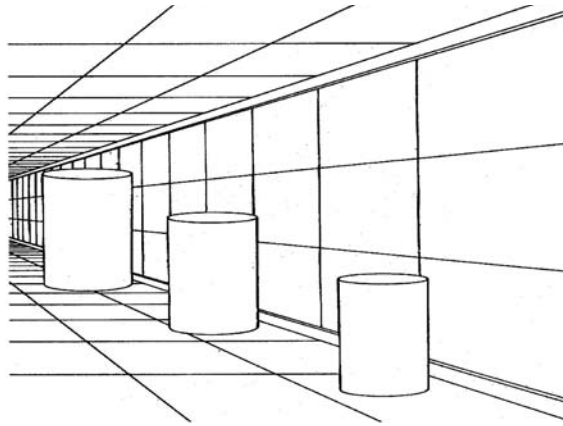


Figure 8-1. *Optical Illusion.*

The picture in the Figure 8-2 is an example of facade lighting that is illuminated from the ground upwards, which causes very unusual shadows and thus is strange lighting the appearance of the building.



Figure 8-2. *Estrangement of a building facade by uplighting (Bartenbach 2009).*

The comparison of two antithetic examples for shop lighting is shown in Figure 8-3. On the left picture many glaring light sources (no shielding) together with specular surfaces (floor, ceiling and shelves with ware) give a glittery appearance, whereas on the right side the light sources and luminaires are hidden, and the ware is in the focus.



Figure 8-3. Comparison of shop lighting: left the light points are in the focus, right the ware (Bartenbach 2009).

Another example is the corridor lighting in Figure 8-4.: on the left is seen a shiny dark floor which appears like a black hole, and on the right surface which are made visible by the illumination.



Figure 8-4. Comparison of two different floor lighting concepts (Bartenbach 2009).

In the museum lighting shown in Figure 8-5 the illumination idea was to use the fluorescent lamps themselves as art. The effect of such illuminations is obvious: the paintings are in the background.



Figure 8-5. *A special approach to museum lighting (Bartenbach 2009).*

Figure 8-6 demonstrates how the appearance of illuminated paintings on a wall can be changed by simple measures. The change in the background reflectance from white to dark increases the visibility strongly.

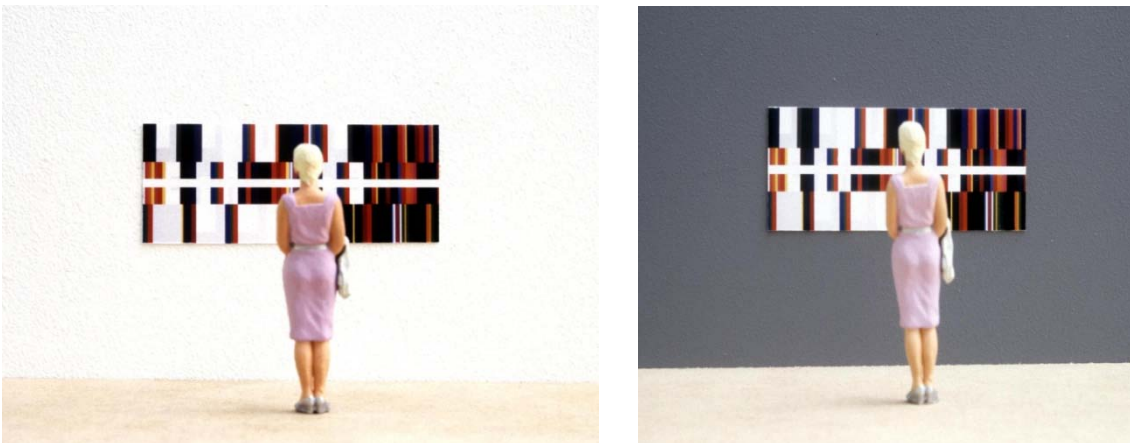


Figure 8-6. *Comparison of two different backgrounds (Bartenbach 2009).*

These few examples make it evident that lighting design is much more than the planning of stipulated illuminance levels.

The aim of an optimum lighting design is to achieve certain appearances and, at the same time, to fulfill the fundamental physiological and psychological visual requirements and to ultimately put the whole thing into effect in an energy efficient manner.

8.2 A technological approach

From an energy point of view, we can identify three steps that transform electrical energy into light: the lamp (light source, including controls and ballasts), the luminaire, and the room. The lamp transforms electric power into luminous flux, the luminaire distributes the light in the room, and the room transforms this light into visible luminances by the surface reflections.

The energetic performance of these different transformations are characterized by the factors

- lamp luminous efficacy (in lm/W, including operating devices)
- luminaire light output ratio (LOR, in %)
- room utilization factor (η , in %).

The 'sum' of these factors gives the ultimate (total) utilization of the electric light installation.

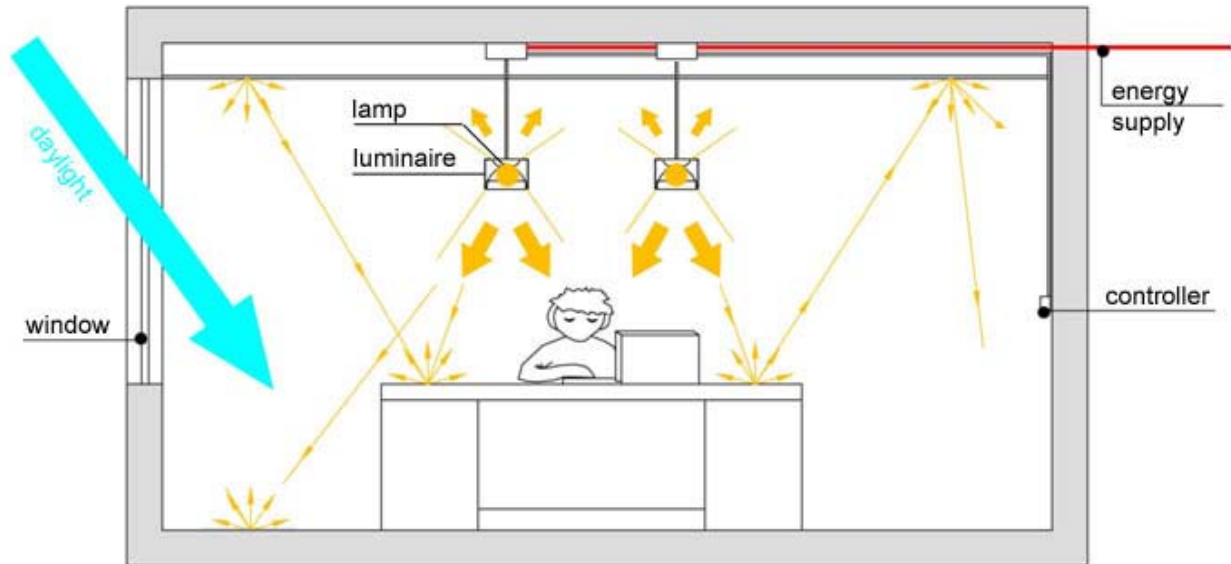


Figure 8-7. Supply chain from the electric power grid to the visual environment.

The energy consumption of the installation is further defined by the operating times, i.e. the need for artificial lighting should be minimized by intelligent architecture and daylight harvesting. Proper controls (occupancy, daylight dependence, etc.) have to be installed to avoid needless operating of the artificial light.

The first key point for an energy efficient lighting installation is the choice of efficient lamps (characterised by the lamp luminous efficacy in lm/W), which produce the proper spectrum (correlated color temperature and color rendering index) and offer the required operating features. Besides the use of energy efficient lamps, the application of high quality luminaires (characterised by the LOR) together with efficient room lighting concepts (characterised by the η) and clever controls, are important for the visual and ecological quality of the whole lighting installation.

The luminaires should not only be a decorative element, but rather a device to distribute the light of the lamp according to the illumination tasks in the room without causing glare, thus creating together with the room surfaces the desired visual environment.

8.3 The role of LEDs

With the emerging LED technology a new white light source is available which offers a great potential for energy efficient lighting. With an efficacy of more than 100 lm/W in the near future, a lifespan up to 50000 h and more, and with easy control and dimming possibilities, LEDs offer all the key features for an energy efficient light source. Additionally, the light output ratios of LED-luminaires are usually much higher than for conventional light sources.

LEDs allow for completely new designs and architectures for lighting solutions, thus opening a new and wide field of creativity for all lighting professionals. At the same time, some old rules and

standards for a good lighting design are no longer rendering, light distribution, etc.). They demand and this needs time to become a widespread and common period, some meanders and mistakes will occur.

As an example, LEDs are very often used as replacement of low voltage incandescent lamps operated like a starry sky (many small light spots without any shading), but there are no clear rules for glare assessment of such an application. Another commonly used CRI for lamps is misleading if applied to LEDs.

There is increased attention for biological (non-visual) effects of lighting in the lighting community. For these different biological effects of light special light spectra may be needed. Although the scientific basics are still too weak to be applied, the lighting industry already offers a lot of so-called 'dynamic lighting' solutions, e.g. to assist the daily activity and circadian rhythm of people. With the mixture of different LEDs it is possible to create almost any desired spectral distribution. This enables the creation of a lighting environment for potential visual and biological effects for human beings.

8.4 Architectural view on illuminants

Light sources or illuminants are defined as devices which transform electrical power into luminous flux. A luminaire is a device which is necessary for the operation of an illuminant. It consists of a lampholder, an operating device for the illuminant together with the necessary electrical wiring, a mechanical construction including a housing and the light directing elements (reflectors, prisms etc.). These light directing elements serve to distribute the light according to requirements and also to shield or fade-out the illuminant.

An architect views the luminaire as a visible part of the interior decoration, whereas a lighting engineer considers it as a device which fulfils photometric requirements. The lighting designer however, wants to be creative with light and to achieve effects. For architects, aesthetic demands on the body of a luminaire (housing) and its arrangement in a room is paramount. On the other hand, the lighting engineer has the photometric requirements in mind (illuminance, glare values, etc.), which come from relevant regulations and the experience of the engineer. The lighting designer, in turn, works with the emotional effects of light, as one can observe from the work of a theatrical stage illuminator. In this case, the spotlights themselves are not important and are rarely visible. Photometric values and requirements are also unknown, only the emotional effect on the stage is what counts.

In accordance with these considerations, the effects of a lighting system can be divided into the following three categories:

- The body of the luminaire as a component of the architecture (decorative)
- The purely visible effect of the light (make things visible)
- The associated aesthetical and emotional effects.

Depending on the objective, the lighting system has its focal point in one of these three categories, but ultimately it is a combination of all effects. Therefore, all of these aspects must be collectively considered. A good lighting design, whether from a specialist or a generalist, always considers these effects as a whole. In the future, further aspects will be more intensively considered. These aspects include energy consumption, environmental impact, maintenance, and cost of the illumination over a life cycle.

8.5 Energy efficient lighting culture

It is essential that in future lighting design practices, maintenance schedules and lifecycle costs will become as natural as illuminance calculations already are. A sustainable lighting solution includes an intelligent concept, high quality and energy efficient lighting equipment suitable for the application, and proper controls and maintenance.

There are activities and efforts underway in Europe (e.g. by CELMA, ELC) to establish a Lighting Design Legislation, which should make sure lighting design follows energy efficient rules in the future. Due to the fact that the objectives of a lighting system can differ, and that there can only be limited standards for architecture and design, we must take care in our endeavor to regulate these areas and to implement limitations. For example, if we set our limitations for the power input per unit area too low, not only the architectural, but also the photometric leeway can be lost and only a trimmed standard illumination with minimal energy consumption would be possible. On the other hand, if we set such a leeway too loose, there would be no effect on energy efficiency.

A more promising prospect seems to be by means of information, clarification and the raising of awareness, together with well targeted technical advancement. This can help to increase the awareness of lighting so that predominantly good and energy efficient lighting solutions will be put into practice.

We have to be careful to avoid overregulation, and we cannot forget that lighting design is essentially a creative design process.

8.6 Survey on the opinion of lighting professionals on lighting today and in the future

8.6.1 Introduction

The survey was conducted during 2006-2007 and the opinions as presented here reflect those of the respondents.

Part of the Annex 45 work was to identify knowledgeable people in the lighting community and to collect information. The goal was to find out how lighting has been developed in different countries within last 5 to 10 years and how people see its development in the future. The experts were also asked what kind of information about (energy efficient) lighting is needed and in what form this information should be provided.

A questionnaire template was sent to key contacts of Annex 45 and they could decide whether to do it by interview or by sending back the filled questionnaire. Altogether twenty-five answers were received from the following eleven countries.

— Austria	1
— Belgium	2
— Canada	2
— China	4
— Finland	3
— France	3
— Germany	1
— Italy	4
— Russia	1
— Turkey	3
— Sweden	1

The members were from the research, manufacturing or application sectors. The following topics were covered in the interview questionnaires:

- Background of the respondent
- History and state of art
- Meaning of lighting for the comfort of indoor environment, health and productivity
- Future of indoor lighting, light sources, installations, integration, automation, daylight, developing needs
- Energy efficiency, lifecycle, environment
- Flexibility, changeability and dynamics of lighting
- Automation
- LEDs
- Information and standardization
- Summary

8.6.2 Results

Background

Respondents were asked about their experience in the lighting field and also the activities of their companies in the lighting field. If the company had several activities it was classified by the main field of activities. For instance, manufacturers of lighting fixtures often have also R&D but they were classified as manufacturers.

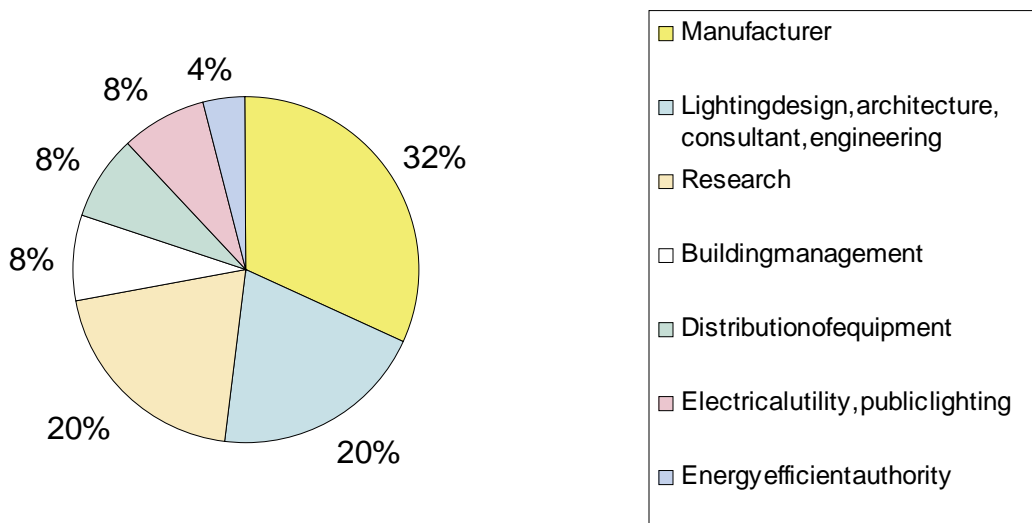


Figure 8-8. Companies' (represented in the survey) activities in the lighting field.

History and state of art

How has lighting been changed during last 5 to 10 years

When people were asked how lighting has been changed during the last 5 to 10 years, more than half of the respondents mentioned the increased demand and for energy efficiency or energy savings. The second largest group mentioned the increase of CFLs and the increase of (small) gas discharge lamps (mainly metal halide lamps) in indoor lighting. After that, the arrival of T5-lamps and the increased use of electronics in the lighting market were mentioned.

The increased use of electronic ballasts as well as control to building management was indicated. Luminaire design has been changing with the new lamps (for instance T5), but also due to new materials. The use of daylight is increasing, partly due to energy savings demand, and this was also related to the increased use of control systems.

The importance of lighting design was mentioned and it was indicated that nowadays it is no longer just electricians that do the design. At the same time, designing has become much easier because of powerful computer tools. The increase of lighting quality, LEDs, reduction of incandescent lamps, dynamic lighting and reduced operational costs were also mentioned in the survey.

Table 8-1. How has lighting (techniques, design, installation, use and maintenance) been changing during the last 10 years?

How lighting has been changing	No. of responses
Increased energy efficiency (of lighting, luminaires, ballasts) and environmental friendliness	13
Increase of CFLs, small gas discharge lamps	9
Increase of T5 lamps	7
Introduction of electronics, digital technology	7
Control (intelligent, digital, integration in building management)	6
Luminaire design, easier to install, better materials	5
Daylighting	5
Lighting design more important but easier (faster)	4
Focus on lighting quality and well-being, health	4
LEDs are entering	3
Reduction of incandescent lamps	2
Dynamic lighting (CCT change)	2
Reduced operation costs (through increased lamp life, lower wattages)	1

The problems of current technology

Table 8-2 **Error! Reference source not found.** lists the problems of current technology as indicated by the survey. The most evident problem was the price of the products; nine respondents out of twenty-five mentioned the price.

Table 8-2. Problems of current technology.

Problems of the current technology	No. of responses
Price (costs)	9
Reliability of electronic ballasts	4
Size and shape	3
Lack of knowledge of best option for the customer, marketing confusing	2
Old installations are not renovated	2
Efficiency	2
Lifetime	2
Compatibility of components from different manufacturers, standardization	2
Problems with lighting controls, lack of control standards	2
Market is slow (takes long time until a new technology can be established on the market)	1
Glare (T5 and LEDs)	1
Feasibility	1
Acceptance by users	1
Lighting design not paid attention	1
Communication between different players	1
Lack of educated professionals	1
Transition period between old and new products	1
Mercury	1

Four respondents mentioned the reliability of electronic ballasts. Three respondents were referring to size and shape of CFL lamps and the fact that they do not fit into old incandescent luminaires. Compatibility of components from different manufacturers was also mentioned related to CFLs and their ballasts. It was also pointed that customers are lacking information on the best options and the marketing can be misleading. Two respondents mentioned that the old installations are not renovated and that there is still need for further improvements in efficiency and life time of products.

How should manufacturers improve their products?

Respondents were asked how manufacturers should improve their products. They could freely express their opinions on the subject and arrange them given nine characteristics of the products in an order from most important to least important. Figure 8-9 shows the aspects that were considered in the survey and the survey results. The largest group of respondents chose energy efficiency as the most important character to be improved.

The respondents also mentioned that manufacturers should communicate more with lighting designers and researchers. The lack of standardization was also mentioned. It was pointed out that new technology has defects in the early stage. Also, more energy saving technology such as PIR sensors was requested.

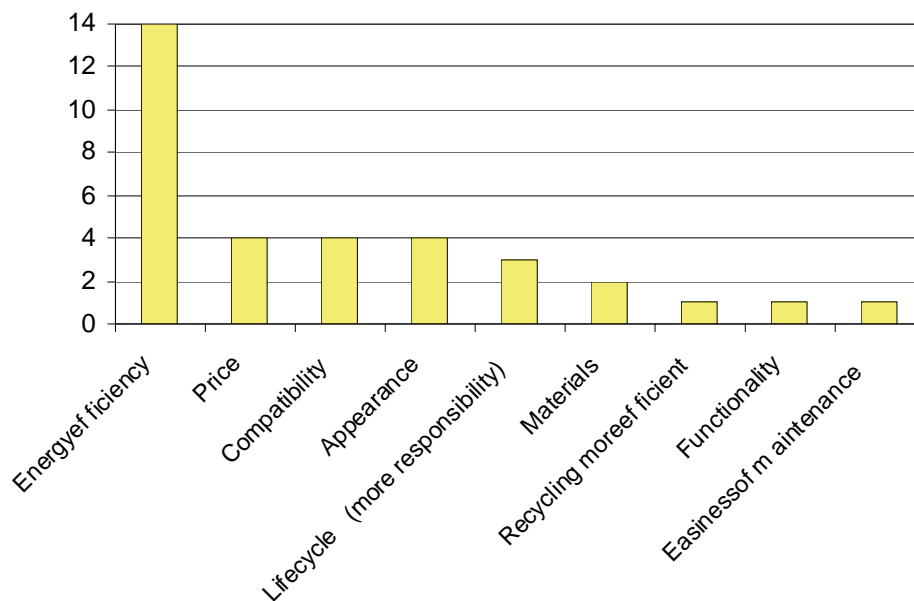


Figure 8-9. Analysis of how manufacturers should improve their products.

Usage, maintenance, needs of development

Opinions on the usage and maintenance of lighting included:

- Significance of the total costs of ownership: More consciousness of this would lead to much higher rate of renovation of lighting, and thus save a lot of energy.
- Maintenance has become more expensive: electrician is needed quite often, faults are expensive, and conventional ballasts more reliable, electronic ballasts becoming more reliable than they were five years ago.
- To make green design a reality, utilities and governments have to work in synchronization with manufacturers and building owners to stimulate the

- use of the most efficient technologies and to compete until market is transformed. Incentives, tax appraisal are good examples.
- More control systems solutions oriented at energy savings and user comfort.

Meaning of lighting for the comfort of indoor environment, health and productivity

View of the importance of human factors (well-being, health, productivity, visual environment) in the future lighting technology

What kind of research is needed? Did you note the importance in your own activities?

The answers for these questions highly reflected the need for more research; 64% of all the respondents expressed the need for more research. They wanted also guidelines and solutions. Few examples of the answers:

- Research on impact of design on vision and human health
- Health, productivity and well-being are very important aspects and much more research is needed to understand the impact of lighting on these quantities.
- Much more research and dissemination is needed to increase the knowledge and awareness on the visual and non-visual effects of lighting. This is a precondition to reach a higher state of the art for our lighting solutions.
- Importance mostly not noted
- There is a lot of research but each study is on a small scale. There is a need for a comparison of all the studies and giving overall conclusions. Industry is interested in more studies on the effects of dynamic light.

Future of indoor lighting, light sources, installations, integration, automation, daylight, most important developing needs

New light sources and ballasts

Two thirds of the respondents mentioned LEDs when they were asked what new light sources are coming on the market. Nine respondents mentioned that electronics, intelligence and communications are increasing (wireless or with wire). It was expressed that the market wants more energy efficient lighting and products with longer life-time.

Table 8-3 . New light sources coming on the market.

New light sources, their components & their important features	No. of responses
LEDs	16
Electronics, intelligence, sensors, communication increasing	9
More energy efficient lighting	5
Longer life	4
Dimmable/smaller wattages high pressure discharge lamps	4
More efficient ballasts	2
Mercury free lamps	1
Controllability	1
Take into account visual and non-visual effects	1

Barriers for new light sources

Price seems to be the most important barrier for the entry of new light sources in the market. The

respondents were also concerned about the quality and performance of new products. It was seen that the pay-back time of new products can be rather high. It was seen that the markets are conservative and it takes time before new products are approved. On the other hand, since volumes are big it takes also time for the manufacturer to change volumes. Some respondents expressed that the management of lighting is becoming more complex and there is lack of standardization and that some dimensions can be inappropriate (CFL vs. incandescent lamp).

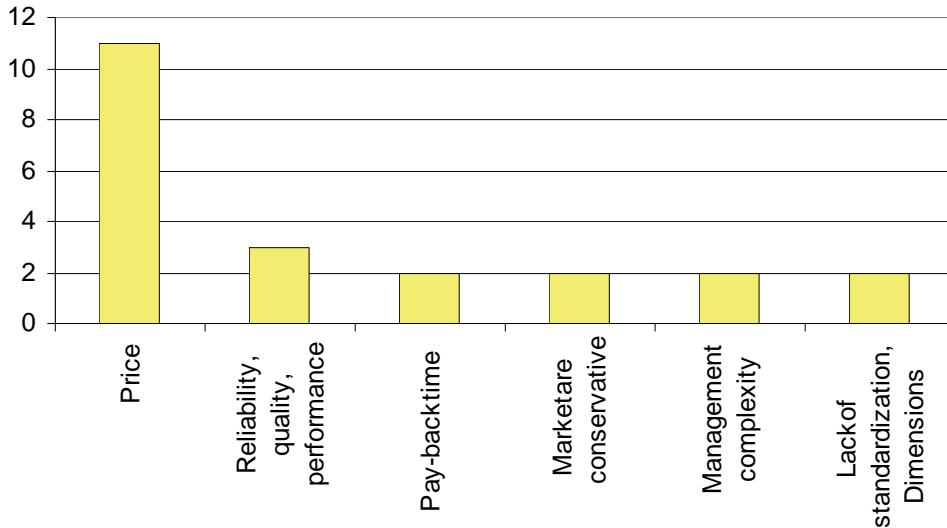


Figure 8-10. Barriers for new light sources.

Trends in luminaires

According to the survey the trend in luminaires is that they will become more efficient in the future. It was seen that energy efficiency will also improve through better lamps and ballasts, better reflectance materials and optics. It was expressed that the design of a luminaire (in-fashion appearance) is becoming more important and luminaires will become smaller; luminaires should be environment-friendly and then parts should be recyclable. Indirect lighting was seen as one trend, that should be avoided. Although one respondent considered this something

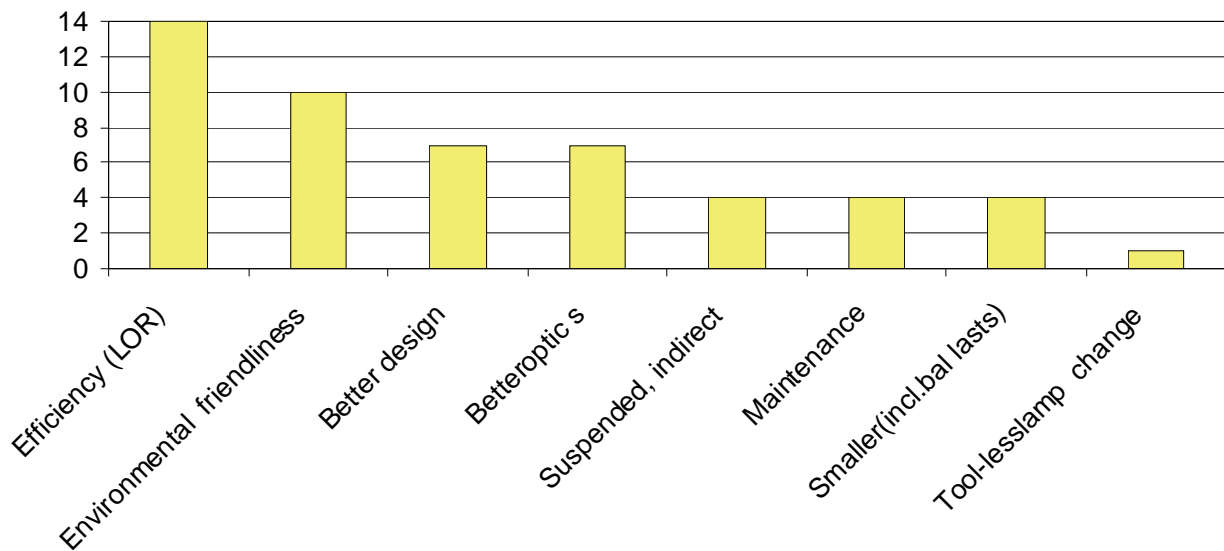


Figure 8-11. Trends in luminaires.

Control methods

When the respondents were asked about the future of lighting control methods most often they mentioned wireless control. Wireless control was also seen as a way for individual dimming and easy access. On the other hand one respondent said “People go in and out of their rooms in their routine work and don’t think about the light. At the beginning it is fun, but then the lighting is left the way it is”. It was seen that the control systems enable energy savings and the use of daylight. Future possibilities of lighting control were seen as dynamic lighting (variable color temperature), intelligent control and adaptive, learning systems.

Table 8-4. Future lighting control methods.

Lighting control methods	No. of responses
Wireless control	7
Daylight use, energy savings	6
Integration to other building systems	4
Individual, personalised dimming	3
Easy access, user friendly	3
Dynamic lighting (variable CCT)	2
Intelligent control	1
Self learning systems	1

Vision of the exploitation potential of daylight and the needs for development to achieve the exploitation potential, the biggest barriers on the point of view of one’s own country

In principle all the respondents that answered this question considered the use of daylight as useful for energy savings, visual comfort, health and well-being. Artificial lighting was also seen as a supplementary light source supplementing and assisting daylight during the daytime.

However, the respondents also found barriers for the use of daylight:

- Lack of general awareness and knowledge of energy saving potential: in many cases the energy efficiency has to compete with low-cost solutions in order to meet budget restraints
- Uneven luminous distribution in the room in daylight conditions
- Lighting design is very important in order to create a proper environment for visual tasks
- Architectural designs are made by aesthetic and local concerns not taking sunlight into considerations.
- Control of artificial lighting has to be done automatically
- Investment costs, difficulties to estimate energy savings
- Thermal problems in summer

The solutions were seen as:

- More education and know-how workshops for architects and electrical/lighting consultants
- Financial and design incentives
- More attention by both architects and lighting designers

Lighting design

The respondents view was that in many cases lighting design is carried out as a side task by people (electrical designers) with low level of expertise in lighting field.

It was expressed that the customers might not be aware of the impact of lighting on the operation to make use of the energy saving potential of a building for lighting design to affect the energy efficiency both in energy saving and good performance. It was thought to be paid for their job; lighting is the last moment when money runs out.

It was seen that poor designs are unable to pay for themselves. The view was that there is a large potential and that good lighting design will have benefits. It was seen that lighting designers are necessary and that during the design and construction, the

The solutions were seen as:

- Raising public awareness about lighting design
- Integrate the lighting design in the start of the building design
- The electrical consultant and the lighting industry have a strong impact to make the decision makers understand. Within 3-5 years the market will be ready to pay for energy saving lighting designs.

Energy efficiency, environment

The experts were asked what actions are the most important in order to improve the energy economics of lighting. They were given three alternatives and the possibility to freely formulate their answer. They were allowed to give more than one answer and therefore all the specified answers were frequently mentioned: “More energy efficient lamps/luminaires” (24 answers), “automation” (22 answers) and “life cycle analysis” (14 answers). Better maintenance, intelligent lighting concepts, including daylight utilization, and quantitative explanations for quality improvements were also mentioned. In the question “what things have to be considered on the environmental issues of lighting” there were also three alternatives and a free formulation possibility. Again, the specified answers were often mentioned: “The long life of lamps/luminaires” (19 answers), “the energy efficiency of lamps/luminaires” (24 answers), “the small environmental burden of lamps/luminaires (in the production, use and disposal/recycling)” (16 answers).

important in order to improve the energy economics of lighting. They were given three alternatives and the possibility to freely formulate their answer. They were allowed to give more than one answer and therefore all the specified answers were frequently mentioned: “More energy efficient lamps/luminaires” (24 answers), “automation” (22 answers) and “life cycle analysis” (14 answers). Better maintenance, intelligent lighting concepts, including daylight utilization, and quantitative explanations for quality improvements were also mentioned. In the question “what things have to be considered on the environmental issues of lighting” there were also three alternatives and a free formulation possibility. Again, the specified answers were often mentioned: “The long life of lamps/luminaires” (19 answers), “the energy efficiency of lamps/luminaires” (24 answers), “the small environmental burden of lamps/luminaires (in the production, use and disposal/recycling)” (16 answers).

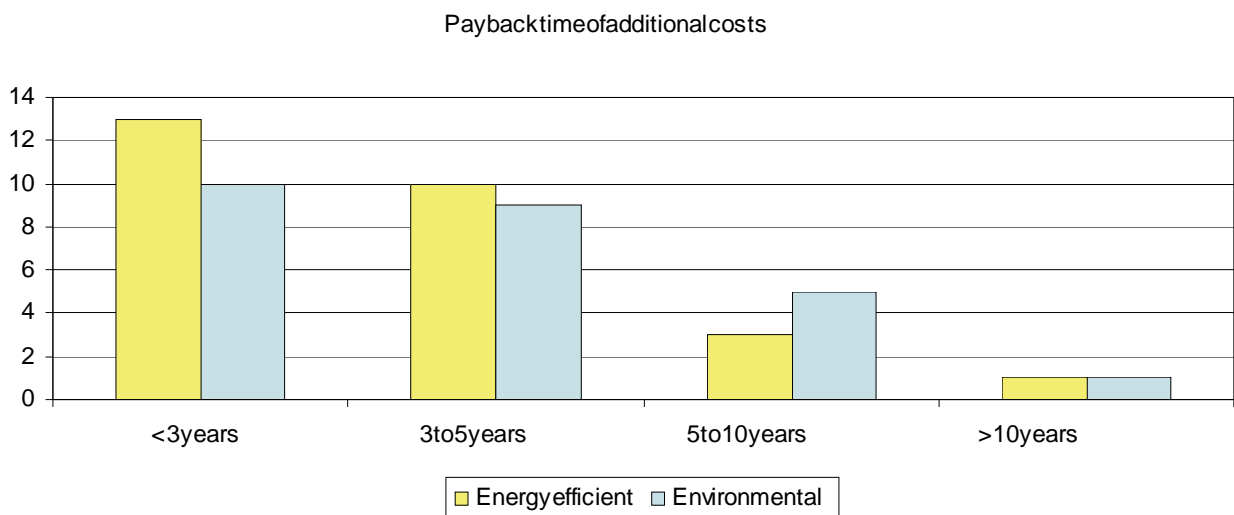


Figure 8-12. Payback time of additional costs of energy efficient lighting and environmental friendly technology.

Thirteen answers saw that the payback time of the additional costs of energy efficient lighting should be less than 3 years, while ten answers saw that the payback time should be 3 to 5 years. One respondent expressed that the payback time should be less than 3 years in domestic lighting and from 3 to 5 years in industrial lighting.

additional costs of energy efficient lighting should be 3 to 5 years. One respondent expressed that the payback time should be less than 3 years in domestic lighting and from 3 to 5 years in industrial lighting.

The view was that the payback times of additional costs of environment-friendly technology can be slightly higher: there were 10 answers for payback time of less than 3 years, nine answers for 3 to 5 years, five answers for 5 to 10 years and one answer for more than 10 years.

Vision of the energy efficiency of lighting in a 5 to 10 year period

- LEDs will probably be significant for general lighting in 10 years
- Efficacy of lamps will increase, integrated lighting concepts and technologies will allow realizing energy saving lighting concepts
- Technology improvements, directives and requirements will be made
- Customers will be interested in energy savings because of the electric bill
- The lighting design might focus more on additional benefits such as health-related aspects or productivity. If these effects can be included in an overall cost/benefit calculation, it could make way for many innovative technologies.
- There is limited possibilities for light sources to improve by raising the luminous efficacy, but a lot of things can be done to luminaries. Market penetration depends not only on the effect of saving energy but also on the cost to get this energy cut. This also implies the barriers for new technology, because more often new technology means more costs.
- With institutional intervention, the market is shifting and will shift more and more
- Disappearance of old fluorescent lamps (T12) and electromagnetic ballasts, great penetration of T5 and CFL lamps
- Costs will probably decrease; that will improve the market. Better and more control systems (too little nowadays).
- W/m^2 will drop down
- Directives will improve the efficiency.
- With the development of lighting technology, the energy efficiency will be higher and higher, this is especially for LEDs.
- New lighting products will improve energy efficiency, LEDs, low wattage HID lamps, and fluorescent lamps with high luminous efficacy.
- Energy is becoming very expensive and every sector has to give importance to it.
- Incandescent lamps will be banned.
- To be on the top of the list for energy saving activities in the building process. To day it is insulation, change of windows etc, which take the money for the lighting installation.

Barriers:

- Costs, stocking and unadjusted marketing directions
- Main barriers will be in the budget for a building.
- Old installations: there is no urge to change them and if they are working they are not changed
- With LEDs the barriers are the packing technology and thermal issues.
- LED luminaires produce electronic waste
- Materials (for instance, fluorescence powder) and packing technology
- New technologies are under the monopoly of specific firms and are being directed by them. Therefore new products are very expensive when they

enter the market.

Vision of the environmental issues in a 5 to 10 year period

- Mercury content reduction
- Government regulations could be the only major factor to improve environmental aspects of lighting
- Reduction of toxic materials in products (lamps, luminaires, etc.) and in the production process.
- Environmental issues are used for marketing.
- Legislation, image, environmentally-friendly solutions, although usage is more important than technical solutions.
- The application of environmental friendly technology should be promoted by the government.
- Also new technology can be harmful to the environment (e.g. content of mercury). The light sources are beneficial to the environment in two ways, one is the benefit coming from them spending less energy, and the second is the efficiency of the new technologies, and the increased product life.
- Materials recycling.
- Ecology becomes a business.

Flexibility, changeability and dynamics, is it important and in what applications?

Automation

Is the changeability of the lighting important?

In what kind of property the physical changeability of the lighting is especially important?

The physical changeability of the lighting was found especially important in office buildings (23 answers), clinical health care (19 answers) and educational buildings (19 answers). All the beforehand defined building types were mentioned by only a few respondents. Table 8-5 shows the survey results on the importance of dynamics of lighting (amount of light, color) in different building types. Dynamics was also found to be important in offices and clinical health care buildings. In residential buildings and shops dynamics was mentioned more than the physical changeability of lighting.

Table 8-5. *In what kind of property the physical changeability and dynamics of the lighting are especially important.*

Building type	Physical Changeability	Dynamics
Office building	23	22
Healthcare, clinical	19	20
Educational building	19	16
Healthcare, not clinical	14	14
Residential building	13	16
Shop building	13	15
Sports building	12	13
Assembly building	12	12
Accommodation building	12	11
Catering building	8	9
Penitentiary building	8	8

What is your opinion about the future of the lighting automation?

Nine answers mentioned that the lighting automation is good and economical investment, ten mentioned that it is good but there are barriers and it is uneconomical, one considered it to be good but uncertain functioning is a problem and two made other points. One respondent saw that before automation there is the intelligence of usage and others saw that automation is good mostly for visual comfort.

What benefits do you expect to gain from the automation of lighting?

Energy savings was clearly the most important factor that respondents expected to gain from automation, Figure 8-13.

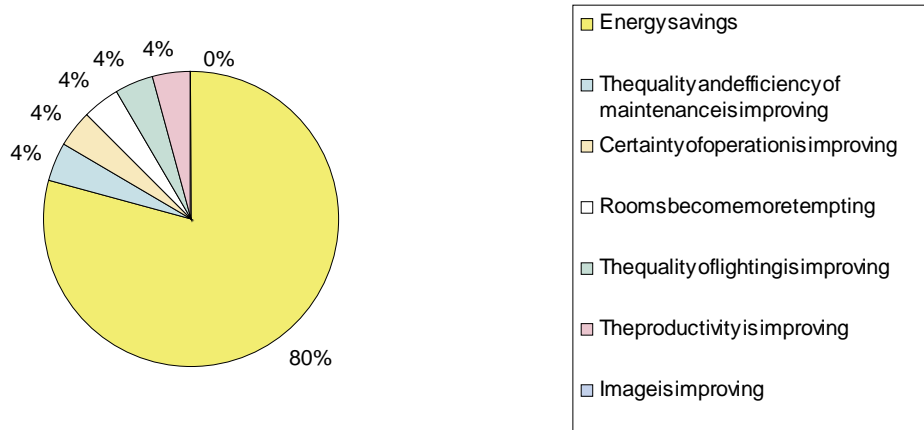


Figure 8-13. What benefits do you expect to gain from the automation of lighting?

Light emitting diodes (LED)

New technology and its integration for buildings services

- Still at small scale use in lighting applications, but already very efficient for colored lighting, EXIT signs with LEDs are common, small accent and step/night lighting with LEDs is more usual to buildings
- LEDs offer a new trend in lighting as they allow completely different luminaire design. There are still some problems in operating them and these problems have to be solved (thermal issues, color etc.)
- Higher and higher lumens output in one package. More stable operation

Where do you see applications for LEDs?

- LEDs can be useful in accent lighting or in environments that require low lighting levels (e.g., patient rooms at night time), retail (dynamic-color lighting, flood lighting of vertical surfaces, delimitation (replacing neon) and seasonal lighting
- Indoor lighting, specialized area lighting (small size allow to be operated in hard-to-reach areas). They can be dimmed easily and have a long lifetime so that they offer quite a few chances in the overall dynamic lighting field.
- LEDs are already being used in traffic lighting, architectural lighting, safety lighting
- At the moment there is only a niche market for special applications, but this will change rapidly in the next 5-10 years. LEDs outperform traditional lamps with their superior lifetime, they offer the possibility of

spectral mixing, are free of IR/UV and very robust. Ongoing improvements in LED technology indicate, that in the near future LED prices are decreasing rapidly, the efficiency is further increasing which opens the way for LED to be the light source of the future with a broad field of applications.

- Outer wall of sky-scrapers, screen of large scale, automotive lighting, flashlights, indicators
- Buildings surface, background lighting
- Mainly for decorative lighting
- General lighting, traffic lighting, vehicles lighting, every lighting application

Ways of illumination?

- Rather than conventional, better and more innovative, as part of decorative elements, wall/ ceiling grid, etc. Cost and innovative technologies are the barriers
- Backlighting of monitors, task lighting, ambient lighting, etc., many setups possible
- Optical efficiency, directed lighting
- Easy to focus on what needs to be illuminated
- For small surface or area

Structure of luminaires

- Standalone (more classic) or integrated into the construction elements
- Luminaires holding LEDs can shrink in size allowing a “lighter” design of the interior.
- Smaller luminaires, integrated in furniture
- Temperature and glare has to be taken into account
- The conventional luminaire industry is not well suited for these new techniques, instead of mechanical (spinning, hydroforming etc. of reflectors, mounting, casing) and electrical construction electronic and small optical construction and manufacturing is necessary
- Panel-like luminaires, linear luminaires
- The smaller the better
- Should release heat easily
- Great flexibility in design, smaller or bigger luminaires.
- LEDs evolve quickly, that is a difficulty for the luminaire manufactures

Low voltage

- Quite suited for this application
- If low voltage can be supplied easily this allows specialized solutions in fields where electrical safety is extremely important.
- Makes easier to hide wires, no electricity hazards, no problems with the temperature like with halogen lamps
- Low voltage is more safe and convenient
- Advantage for some applications: Wall, floor, under the hand, under table, in the seat; the very easy utilization with batteries will create a specific sector for itself.

New installation practices?

- Correct installation of LEDs will require specialized contracting teams that have their own designers and can control the purchase, installation and commissioning of the LED design
- This will be answered in the future by applying it in the real world.
- LED-luminaires may produce electronic waste (trend to throw away elements and luminaires, no replacements due to long lifetime). We have to establish industrial standards for LEDs itself, holders, controls etc. (comparable to the ones for common light sources) to encourage sustainable LED luminaire design.
- Only in detail, does not have many effects on macro platform
- Yes, due to the long lifetime

Integration in building structures and to other energy systems

- Requires a lot of careful planning and may need specialized subtrades
- I do not see any difficulty in integrating LED luminaires in buildings. Ballasts can be designed such that they can be controlled by building management systems.
- Integration of furniture, OLEDs can be used, for instance, as wall papers
- Lumen maintenance, costs

What are the worst barriers?

- Cost and knowledge of procuring the right equipment for the application
- Thermal management issues, luminous efficacy, color rendering
- Users are slow to accommodate, building lifecycle is long
- Reliability, lamp life, price
- Glare, price, energy efficiency (at the moment)
- Industrial standards are not available (holders, control and ballast, platines, etc.). High prices, high risk (not fully developed state at the moment, LEDs in practice do not fulfill the promises), fast developing LEDs.
- Lumens efficiency, packing technology, second optical design
- Heat, the lack of standard and the fact that the optics are not specified yet. The concepts haven't found their place yet.
- Let's not say barriers, but disadvantages; it hasn't reached high power values yet, highly efficient light has not been obtained yet, secondly we can't use it as easily as it would have been in normal network voltage, in addition to that there's the heat problem in high power LEDs. The LED is small but for cooling it, 50 grams of aluminum cooler is used per 1 gram of LED.
- Reliability
- Not possible for the owner to know about the durability of the installation.

Information and standardization***What is your level of knowledge on standards, directives, recommendations, energy efficient techniques and design?***

Fifteen respondents answered that their knowledge is high or good. Three answers mentioned that

their knowledge is common or adequate.

Is education needed on energy efficient lighting technologies?

Sixteen respondents answered yes.

Is publication needed to promote new technologies?

Sixteen respondents answered yes. Three respondents said that there already exist standards; two of them considered that the standards are not used enough.

Whom should act as sources for neutral information concerning new technologies?

Few respondents said that information is needed from all sources. It was also pointed out that research institutes do not necessarily have the funding for the information delivery.

Table 8-6. Whom should act as sources for neutral information concerning new technologies?

Whom should act as information sources	No. of responses
Research institutes	25
Associations like Illuminating Engineering Societies	18
Manufacturers organizations	10
Private info services	9
Others: utilities, governments, press, governmental organization etc.	4

Are you ready to pick up information? From what areas of lighting more information is needed?

Information is needed about the total costs of the lighting (17 answers out of 25). Information is also needed about the systems and the choice of lamp type and luminaires (16 answers). Energy efficiency (15 answers) and choice and use of control equipment in different installations (13 answers) were also often mentioned. It was seen that more information is needed about techniques, environmental issues, lamp lives and illumination design. Information should be provided by different means, the most popular was internet (21 answers), seminars (19 answers), brochures (18 answers) and CDs (10 answers).

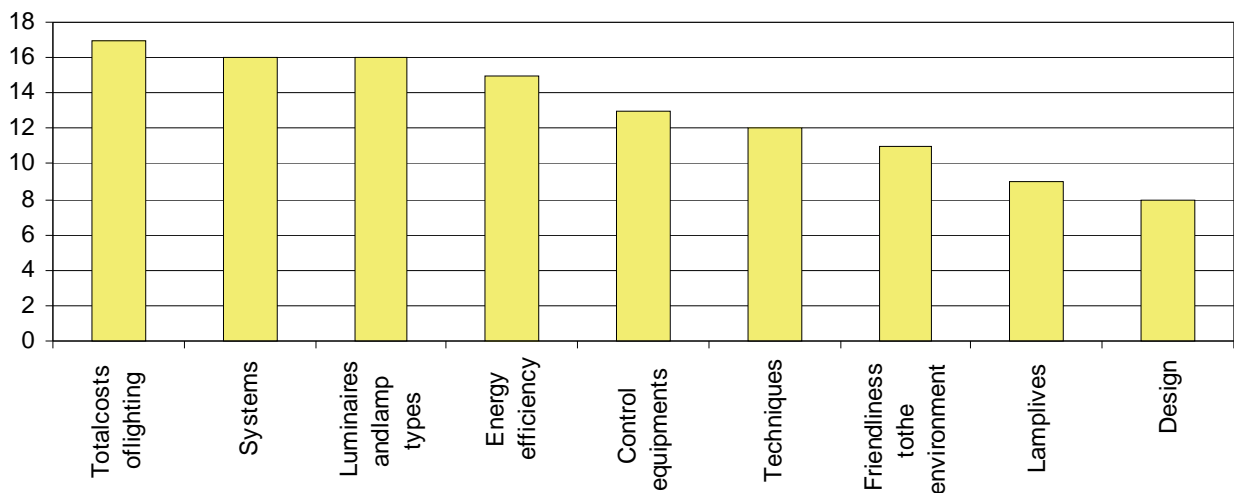


Figure 8-14. From what areas of lighting more information is needed.

8.6.3 Summary and discussion

In the summary the respondents were given a list of issues of lighting and asked how important they considered them. They could rate each issue from 1 to 6 (1 being not important and 6 very important). They were asked both their own priorities and also what they think that the end-user would appreciate. The same number could be given more than once for different issues. The results are shown in Figure 8-15.

energy efficiency being the most important. However, the respondents did not think that the end-user appreciates appearance (5.1), amount of light is enough (4.8), price (4.8), quality of lighting (4.7) and energy savings (4.7). The issue trend was valued for 3.9 by respondents and 4.0 by what respondents thought end-users appreciate.

Most of the issues were considered important, energy efficiency being the most important. However, the respondents did not think that the end-user appreciates appearance (5.1), amount of light is enough (4.8), price (4.8), quality of lighting (4.7) and energy savings (4.7). The issue trend was valued for 3.9 by respondents and 4.0 by what respondents thought end-users appreciate.

energy efficiency being the most important. However, the respondents did not think that the end-user appreciates appearance (5.1), amount of light is enough (4.8), price (4.8), quality of lighting (4.7) and energy savings (4.7). The issue trend was valued for 3.9 by respondents and 4.0 by what respondents thought end-users appreciate.

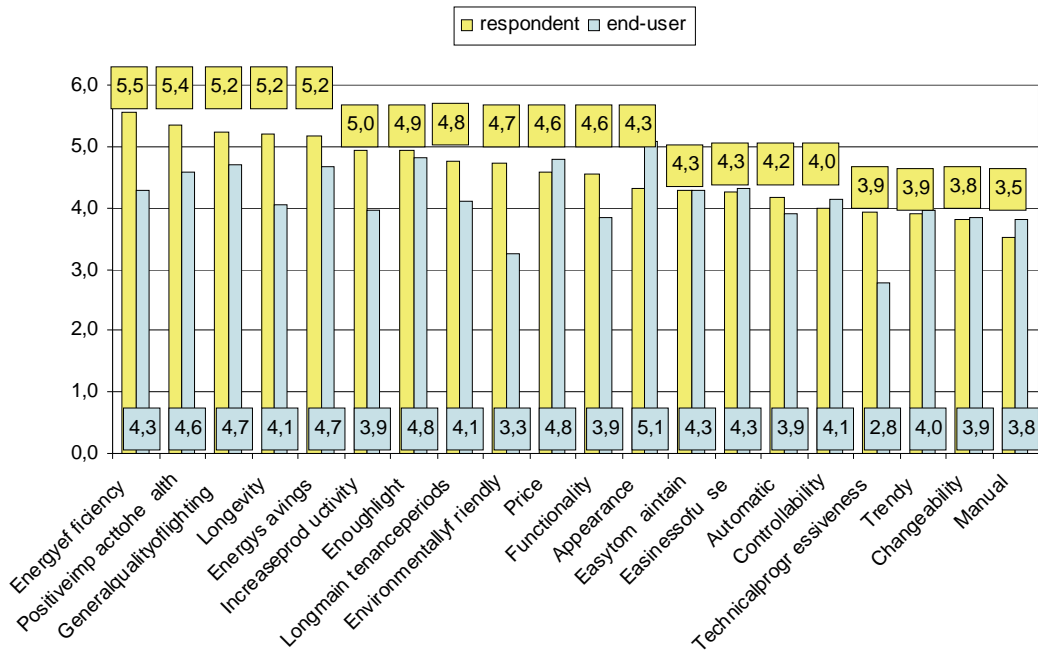


Figure 8-15. Importance of different issues of lighting.

The respondents were also asked if they think that lighting has an effect on different aspects of property. They could value them from 1 (not important) to 6 (very important). The average values are shown in Table 8-7.

lighting has an effect on different aspects of property. They could value them from 1 (not important) to 6 (very important). The average values are shown in Table 8-7.

Table 8-7. Evaluation of lighting effect on different aspects of property.

Evaluation feature	Average given
Satisfaction of the users	5.3
Quality	4.7
Desirability as a working place	4.7
Image of the company	4.5
Easiness of renting/selling of property	3.8

The survey indicated that energy efficiency of light sources has been increasing during the last 5 to 10 years. This has happened through more efficient light sources like compact fluorescent lamps and LEDs (electronic ballasts) and control systems (electronic ballasts) and control systems. Problems of reliability. On the other hand, it was seen that the current technology were seen to be high priced and the market is slow and it takes time before the new technology can be established on the market. Further improvements on energy efficiency are still needed. When asked how manufacturers should improve their products 14 respondents out of 25 said that they should improve the energy efficiency.

Human factors (well-being, health, productivity, visual environment) were considered very important. But the general opinion was that there is not enough knowledge on these and more research work is needed to understand the impact of lighting on human factors.

The survey indicated that in the future new light sources on the market are LEDs and dimmable and/or small wattage high pressure discharge lamps with longer life times. It was also seen that electronics, intelligence, (wireless) dimming, sensors and communication are becoming more commonly used. The view was that the luminaire efficiency (light output ratio) is increasing. Barriers for new products were seen to be the price (long payback time and also the lack of information of the total costs), reliability and the conservativeness of the market. It takes time before new products are approved and on the other hand since volumes are big it takes also time for the manufacturers to change volumes. The majority of the respondents answered that the payback time for the additional costs of energy efficiency should be less than 5 years (85% of answers) and moreover 37% answered that it should be less than 3 years. The attitude for the additional costs of environmentally friendly technology was parallel, 76% saying that the payback time should be less than 5 years and 36% said that it should be less than 3 years.

The respondents saw that in the future, the energy efficiency will increase through technology (LEDs, CFLs, T5s, luminaires) and also because of the increase of the electricity price. Further causes for improve in energy efficiency were seen to be the new directives and requirements (for instance, the ban of incandescent lamps). Energy savings was found to be the most important factor to be gained from automation.

The respondents expressed that LEDs are coming on the market, but at the moment LEDs are on special applications like traffic lighting, architectural lighting and safety lighting. Thanks to lowering prices and increasing efficacy and long life time LEDs will be the light source of the future with a broad field of applications. It was seen that LED luminaires will be smaller, perhaps integrated in the furniture or construction elements. Barriers for LEDs were seen to mainly be high price, thermal management issues (need for heat sink) and luminous efficacy. As barriers, the lack of standards and glare and the durability of the installation were also mentioned. The respondents are needed to promote energy efficient lighting; research institutes were seen as the best source of neutral information.

According to the survey there is demand of energy efficient products in the market. In the near future this demand will be increasing through the increase in prices of electricity, the increasing awareness of environment, and directives and requirements. However, it was seen that the energy efficiency of lighting products has been increasing for last 5 to 10 years with new light sources, electronics and control systems. The view was that full advantage has not been taken of the new products which are already in the market, as lighting market is conservative and the renovation rate is slow.

The survey indicated that information of the new technologies and also public actions and awareness are needed to

technologies should be provided to the end users, promote energy efficient lighting technologies.

References

Bartenbach 2009. Bartenbach Lichtlabor, Austria

