It’s LED that makes the future bright

LED – Light in public space scientific report

LED
Light in Public Space

The project

The LED Light in Public Space project, partly financed by the South Baltic Programme, include twelve partners and three associated partners around the South Baltic area: City of Kalmar (lead beneficiary), Bad Doberan County Council, Municipality of Oskarshamn, City of Gdansk, Institute of European Initiatives (Gdynia), City of Rostock, Hochschule Wismar University of Applied Sciences, Technology, Business and Design, Linnaeus University (Kalmar), University of Klaipeda, Public Institution Strategic Self-management Institute (Klaipeda), Energy Agency South East Sweden (Oskarshamn), City of Wismar, Kalmar Energy AB, Sustainable Sweden Southeast (Kalmar) and Lighting of Roads (Klaipeda).

The project aims to provide verified arguments for conversion of city and road lighting to energy-saving, environmentally friendly and versatile LED-technology, promoting the LED-technology, creating know-how and raising the awareness for energy-saving. It shall create test pilots and best practices on innovative methods of public lighting in cities and regions.

LED Light in Public Space project was in operation for the tree year period September, 2009 through September, 2012.

The report

This report has been produced by an editorial work group featuring the project component leaders **Bertil Eifrém** and **Ulf Rickardsson**, City of Kalmar, Sweden, **Eva Hjälmered**, Municipality of Oskarshamn, Sweden and **Jan Ejhed**, Linnaeus University, Kalmar, Sweden, together with **Thomas Römhild** and **Peter Schmidt,** Hochschule Wismar University of Applieed Sciences, Technology, Business and Design, Wismar, Germany (henceforth named University of Applied Sciences), **Eleonora Guseinoviene**, University of Klaipeda, Lithuania and **Stasys Paulauskas**, Public Institution Strategic Self-management Institute, Klaipeda, Lithuania.

Main contributors in academic authoring

Part one, ***Where did we come from? Where are we heading?*** was mainly written by **Thomas Römhild**, **Saurabh Sachdev** and **Peter Schmidt** at University of Applied Sciencies, Wismar, Germany. Assisted by **Jan Ejhed** and **Effrosyni Stragali** at Linnaeus University, Kalmar, Sweden.

Part two, ***LED, what is it?*** was mainly written by **Jan Ejhed** and **Effrosyni Stragali** at Linnaeus University, Sweden. Assisted by **Eleonora Guseinoviene**, University of Klaipeda, Lithuania and **Thomas Römhild, Saurabh Sachdev** and **Peter Schmidt** at University of Applied Sciencies, Wismar, Germany.

Part three ***The Project installations*** was mainly written by **Ulf Rickardsson**, City of Kalmar, assisted by members of the respective municipalities.

Part four ***What do we expect and need from the future*** was mainly written by **Thomas Römhild, Saurabh Sachdev** and **Peter Schmidt** at University of Applied Sciencies, Wismar, Germany.

All parts of the report reflect the author's and partner's views only. EU Commission and the Managing Authority are not liable for any use that may be made of the information contained herein.

The appendix

Additional material is published as appendix to this report on the project website ***ledllightproject.eu.*** A complete list of articles in the appendix can be found on page 85.

Content

A Bright Future?

Will the new LED (Light Emitting Diode) lighting technology make the future bright? If so, when will it start? Considering the cost, is the time to do this giant technology leap really here? Frankly, why should we care? What's wrong with present-day street lighting?
Well, one answer could be that forthcoming regulations will force replacement of old, energy-consuming types of street lighting. Another that the traditional technology does not take the pedestrians perspective. And yet another, that LED will not only provide light but also a mich nicer urban environment!

Three years ago, fifteen skilled partners across the South Baltic Region got together to deliver answers to questions like the ones I cited above. Members of the group were universities and institutes in Germany, Lithuania, Poland and Sweden (see fact box on previous page for more).

At the time, few of us realised how big a technology shift we were centred at. The industry was in the middle of a rapid change, the market was confused and reluctant to be tilled in front of the industry. To put it modest, the last three years the public lighting market has been somewhat turbulent.

Of course this has from time to time influenced our project with both excitement and navigation complications. However, with three universities excelling in skill on board and a close and fruitful dialogue with leading market actors, I dare say the project has been able to gather knowledge resourcefully.

Fortunately, we have also been able put this knowledge into action in test installations, thus delivering a pedestrian perspective to the design and realisation process of LED installations in the participating cities.

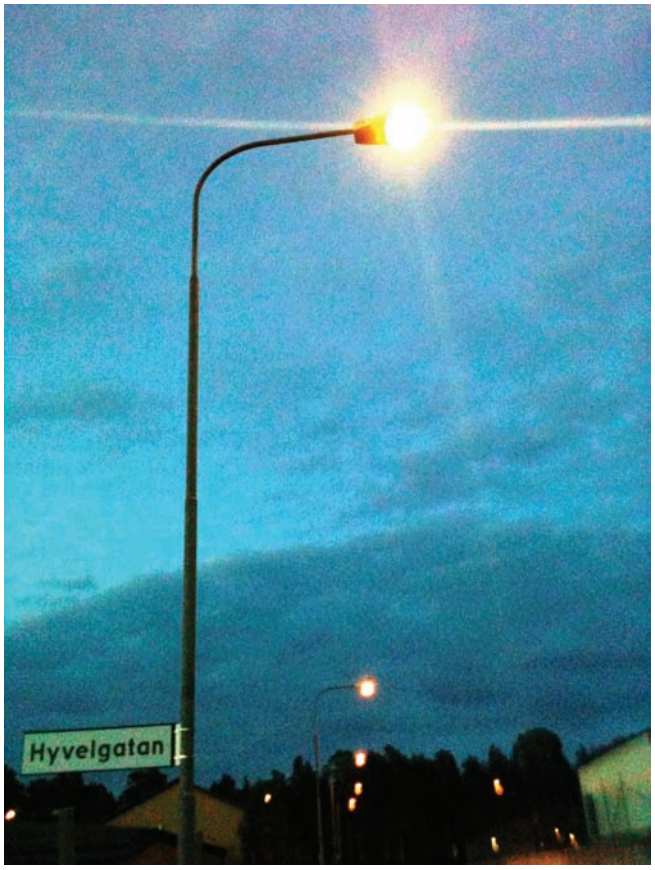
In this report the *LED – Light in Public Space* project partners, summarize the project's most important results and conclusions. Our ambition is to inspire city planners, specialists and decision makers in public lighting, but also to assist and promote good solutions.

We believe that capable and skilled buyers and users are the most important requisite in the ongoing and fast accelerating conversion to energy-saving, environmentally friendly and versatile LED technology.

Certainly, LED lighting can contribute to a brighter future. The time is here and it is also economically motivated to get started.

But it will not happen automatically. Proficiency and understanding of the new technology and its possibilities are essential. To this end, we hope you will find our contribution beneficial.

Kalmar, Sweden, September 2012
Bertil Eifrém
Project Manager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LED
LIGHT IN
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FINAL CONFERENCE | 27th - 29th MARCH 2012

The LED – Light in Public Space Project 2009-2012

THE LED – LIGHT IN PUBLIC SPACE PROJECT WAS BASED ON NATIONAL ENERGY action plans, specifying how the EU member states intend to achieve their adopted energy savings target by 2016. The project aim was to provide verified arguments for conversion of city and road lighting to the energy-saving, environmentally friendly and versatile LED technology, promoting the LED-technology, creating know-how and raising awareness for energy-saving. The project created test installations and best practices on innovative methods of public lighting in cities and regions. Focus was put on investigating effective measures to reduce the energy consumption and CO2-emissions caused by public lighting. The project was targeted to establish a network at international, national, regional and local level, in order to adapt the existing LED solutions to municipal needs and stimulate and facilitate rapid conversion to LED.

Lighting affects how we feel, what we feel and how we perform at work. Providing street lighting is an important – and expensive – responsibility for a city. Inefficient lighting wastes significant resources each year, and poor lighting creates unsafe conditions. According to a poll conducted by Novus Opinion, on behalf of the Swedish lighting organization *Belysningsbranschen*, lighting is a more important factor to make cities safer, than increased presence of polices and guards.

Municipalities light up cities to make them safer, but also to create areas of comfort and beauty. The issue of energy efficient lighting is becoming more and more important both for companies and public actors. Due to the EU directive for Eco-Design 2009/125/EC, high-pressure sodium lamps will be faded out in 2012 and 2015. In 2017 the requirements for metal halides will be sharpened.

Methodology

The advanced European methodology of *sustainable innovation* was applied in the project, including *holistic, life cycle, virtualics, strategic self-management* and *Triple helix* approaches. Economic, ecological and social priorities were taken into account with responsibility for actual and future generation.

Three-stage multidisciplinary research planning was used: a) exploratory, b) analytical and c) experimental. Hypotheses were checked by use of expert and public polls. Project team involved scientists and experts from large scale science disciplines: Philosophy (applied sociology, psychology, and ethics), physics, technology and social sciences. Project partners were responsible for researches and its results in their own countries. Targeted co-operation between national universities, research institutes, municipalities and producers were used to assure implementation of project tasks.

Situation in the South Baltic region

In order to know what kind of installation cities need and want as well as current installations and maintenance needs, a mapping of the project partners was done to discover types of light sources.

Type	Kalmar	Gdansk	Rostock	Klaipeda	Total
Incandescent	24	0	0	24	**48**
Low voltage halogen	0	0	0	42	**42**
Mercury	1 546	426	468	0	**2 440**
Tubular fluorscent	234	735	0	34	**1 003**
Compact fluorscent	0	510	70	191	**771**
Metal halide	175	1 043	36	76	**1 330**
High Pressure Sodium	11 350	12 583	20 759	12 765	**57 457**
Low Pressure Sodium	0	0	23	0	**23**
LED	0	60	0	0	**60**
Total	**13 329**	**15 357**	**21 356**	**13 132**	**63 174**

In the selected area 85 % of the light sources were HPS (High-pressure sodium). The reason for this is that HPS produce a lot of light. However they do not produce so high CRI (Colour rendering index). Since energy efficiency was the most important, lm/w is more prioritized than for example high CRI. In 2009, 12 % of the light sources were mercury, which was used before HPS was installed. Up to then, most of the partners planned to increase the amount of HPS or Metal halide since it has better lm/w than Mercury. By 2015 Mercury retrofit will be forbidden and since the lm/w is almost as high for HPS as for LED, LED should be the lamp type that we replace mercury with. Main focus when installing new light should instead be on quality. That means the right amount of light for a space instead of as much light as possible for the same amount of energy.

Lighting can be improved with LED. With LED:s we can control *lifetime, CRI, Kelvin* and *light output.* A couple of other factors were discovered in the investigation stage and were proven valuable for the continued work:

Standards. There is no standard because there are too many different authorities who are responsible. If we add another standard we have to rethink the existing standards. Regulations and recommendations are there we have to be aware of them in the project.

Pedestrians. When discussing users' need, the pedestrian was focused, this was fruitful because this is a good opportunity to find out what is good for street lighting.

Users' demands and demands on different environments

Different user groups of a lighting installation imperatively have different demands, especially in terms of light level, light colour or glare. But even beyond that the visual perception of different user groups varies with their age, surrounding and expectations. The better the different user demands are understood, the higher the possibility that a lighting installation meets the necessities of the different users and the more successful the installation.

In addition to the physical nature of the group of people using the space, the lighting demands of the users depend on the task they want to fulfil at a certain space: the function. It is a huge difference when someone read a book with small letters for some hours or waiting for the bus for some minutes.

Light has several functions. We need light for orientation, recognition of small details, creating a special atmosphere, feeling safe etc. A working space, where people work for several hours requires other lighting conditions than a space used for relaxation or transition to another space.

Designing a light installation means including various user demands, as well as determining the priority. How the space should be used and at what times. Is it necessary to light the playground at night? Do we perhaps even want to discourage use of the space during certain hours of the day? One function of the lighting can be to suggest a certain kind of use, or to avoid another.

The results of the surveys are in the analysis structured as four central concepts affecting the human requirements of perceiving.

Visibility – the ability to apprehend objects, details, occurrences and courses of events. Light factors to consider are for example brightness, colour rendering and lighting distribution.

Spaciousness – the ability to appreciate room, space and three dimensional relationships. Light factors to consider are for example colour contrasts and colour temperature.

Atmosphere – the psychological status effecting user's moods and feelings are basis of safety and security. Light factors to consider are for example colour temperature, brightness and direction.

Rhythm – describes the time and effects at our circadian systems as well as mental alertness and well-being. Light factors to consider are for example the dynamic and changing factors of the light.

A good lighting quality is a balanced compilation of these four concepts and the main result of the partners' practical investigations is that the LED lighting technology offers a much wider range of possibilities for satisfying these four concepts.

Standard development of public lighting

Standardization is a dynamic process and standards have to be updated as there is continuous development and progress of new technologies, in this case the technology of LED. Lighting standards for pedestrians have almost been a by-product of lighting standards for car traffic. This because it was believed that driving requires a better visual perception of the space than pedestrians walking. Presently, having realized that the importance of "right lighting" is the same in both situations, attempts to understand the differences and establish new standards that fit in each occasion are incresing. It has become clearer that the purpose of public lighting not only is to make streets safe and to prevent crime and accidents. Present lighting projects are indficating the change in this attitude.

Standards, however remains quantitative, based more on the brightness, the glare and the uniformity of the light distribution. They are merely recommendations without qualitative aspects. It is really important to establish not only quantitative but also qualitative standards based on good lighting conditions for the user.

City planners and architects consider the shape of the luminaries and how they appear in daytime. On the other hand, technicians take into consideration the practical issues such as light performance, durability and resistance to vandalism. It is time to combine these aspects and develop new standards based not only on the quantitative nature of light but also on the quality and appearance of it.

Lighting designers have to reshape the cities, organize and structure the surroundings, giving a form that satisfies the varying demands of the people that use the space. When creating new standards for practical outdoor lighting applications, the recommendations are to investigate:

- Sites and typology.
- Highlight urban features.
- Hierarchy of urban elements.
- Surroundings.
- Transition spaces.
- Intersections.
- Emitted obtrusive light – Glare – Cut-off angle.
- Light distribution – Design possibilities and Light in different weather conditions.

It is also important to remember the humanistic approach, to consider the human needs and requirements for outdoor urban spaces. This includes light designed for pedestrians, perception of the space and people with disabilities. Based on human conditions for visual perception and the information process of the brain aspects such as perception of the space, perception of three-dimensionality of the

viewed scene, vertical and semi-cylindrical illumination and facial recognition are of great importance as well for feelings of safety as for feelings of attraction.

The new technology of LED can improve the lighting technology, and the electronic control system. The reliability of the new technology is getting better, the urban light can be controlled in a dynamic way, the control of spilled light is better.

When formulating a new standard increasing the safety, security, orientation, identity and the architectural and aesthetical aspects play an important role.

The production and development of standards is a really complex process, as standardization is a dynamic process and standards have to be updated as there is a continuous development and progress of new technologies and in this case the technology of LED. It is essential that all the organizations and institutions that are involved in the field of lighting and standardization take discussions also with users, municipalities, lighting designers and engineers and not only with manufacturers, in order to deliver standards that guarantee light of great quality in public spaces.

Installations

The project had six installation sites: *Kalmar (SE), Oskarshamn (SE), Gdansk (PL), Wismar (DE), Rostock (DE)* and *Bad Doberan (DE)*. The cities and sites possess different surroundings, needs, purposes and possibilities.

Quite frequently, municipalities feel they need to wait sometime before replacing old installations with LED:s, because of the cost and the adjacent development of LED technology. From one standpoint, this is understandable as the light output is continuously improved, but there are also other points of investigation and progress which are not directly affected by the light output and could be used in a design that could last longer: How can LED be integrated in an urban environment; Controlling and monitoring of LED:s; Design of fixtures; LED light distribution; Standards for mounting LED, etc. When planning the installations information and know-how about standards, users' needs and demands etc were taken into consideration in order to have test installations that fulfil the needs and wants that suits the site and surroundings.

The six test sites are complementing each other in their differences. Common for them all are the focus on the users' need, the interest in saving energy and the possibilities of a flexible control system.

That LED is a light source that fulfils the demands of standards and regulations in values such as light levels, brightness, uniformity, etc., was indeed experienced through the pilot installations. Also, LED installations were undoubtedly in all projects an energy efficient solution.

In many cases, such as the project in Rostock, municipalities can save great amount of energy due to lower energy consumption of LED:s.

Moreover, LED also offers great design possibilities. This was noticed in project in Gdansk during which luminaries were designed for the recreation of this area. It is also a RGB light source that can be controlled through and used in design projects.

LEDs offer a better quality of light in comparison to old light sources, better light distribution with great uniformity as the project experienced in Frimurarvallen park installation in Kalmar. It is a light source with a high colour rendering index (CRI) value. This was obvious at all the pilot installations of the project, but mainly in comparing old and new installations in the passage in Lindö, in Kalmar. This new technology offers a variety of different correlated colour temperatures (CCT) as shown in the pilot installation at the schoolyard in Wismar.

Main achievements

Significant results were achieved in all stages of LED in public space innovation life cycle: Raised awareness of the advantages of LED technology due to a targeted information campaign; Increased commitment to the implementation of LED in public lighting to save energy and costs; A triple helix network for lobbying of LED technology; Durable education effects was achieved; Guide on lighting demands & inventory of status of technological development was worked out; Developed approach to standards for public lighting by LED; Design manual for planners & manufacturers was prepared; Pilot LED lighting installations were made and results were evaluated; Best practice models and ap-

plicable LED solutions for lighting in public space as convincing arguments for future investments into lighting infrastructure in cities and regions of the South Baltic region and beyond were identified and stated.

LED cluster building

Organizational mechanisms of innovations are transiting three qualitative leaps: a) single actors in the market (research institutions, academic bodies, business enterprises, etc.), b) business association and networks, c) clusters.

LED innovation in public space of South Baltic Region is in the beginning stage as non joined starting activities of single business enterprises, universities and research centres. The organizational role of the LED project was realized trough market research to establish networks of potential participants of LED innovation activities on Triple helix mode by joining business enterprises, universities and local/regional authorities. The principle of Triple helix was strongly held in all events of the project LED. This was possible because project team was designed with partners and associated partners from research/academic, public administration and business spheres in each country: Sweden, Germany, Poland and Lithuania.

The further LED innovation will ask of more strong and legislative joined groups of actors, defined as LED clusters. Main principles of LED cluster building were defined as group of enterprises and institutions, which activities forms life cycle chain of LED in public space innovation. The main self-management organ of LED cluster should be LED in public space Council, which joins representatives of business, science and public administration/policy.

Four branches of LED cluster were provided: *Strategic Management, Industry, Logistics* and *Infrastructure*. Strategic management branches should involve functions and bodies of the cluster strategic planning, marketing, innovation and financing. Industry branch may involve LED equipment production factories, construction companies, service and technical maintenance providers also equipment utilization specialists. LED logistics chain should assure joining of sell and purchases, storage and transportation of equipment. LED infrastructure branch should care for development of standards, lighting master plans, security and safety of pedestrians and transport.

Future development

The LED technology offers possibility to design complex control scenarios that can dynamically change the characteristics of light with changing requirements, uses and needs.

Further extension could include utilising sensors for proximity, user intensity, weather and climate, that could control parameters like brightness, contrast, light colour etc. Functions that previously could not easily be controlled, for instance light distribution and colour rendering properties, can now be so using LED technology. This provide optimum design possibilities for use or function with the appropriate light quality as well as maximizing energy saving potential.

LED Technology can play a crucial role, providing precise light distributions, different light distributions, on demand, controllable light colour and colour rendering qualities, on demand luminance and luminance levels, integration of sensors and other services.

Urban Regeneration

Lighting along with other urban design strategies is being used as a tool for urban regeneration. The city of the future has grown as a singular entity; the future city cannot have concentrations of development whilst the rest suffer from poverty, marginality, ignorance and exploitation.

Social and economic inequalities are major challenges facing the city today. Any urban strategy has to ensure the removal of such social, economical and urban inequalities. Through precise light distribution and focusing light, it is possible to bring light to places, which earlier, due to disturbances to the surroundings, could not be illuminated.

It is now possible to have sharp contrasts between lit and unlit surfaces, clearly distinguishing different zones in an urban landscape. The new design possibilities can be used to meet new user requirements, thus better fulfil needs and demands of the citizens.

Part one
Where did we come from?
Where are we heading?

Society, Light and Technology

LIGHT HAS ALWAYS EVOKED RESPONSES IN HUMANS based on deep feeling and emotional reactions rather than on reason or thought. Darkness or night time has traditionally symbolised chaos, dreams nightmares, ghosts, demons and all the irrational fears of the human mind.
Night has come to represent the human civilisations eternal struggle to master the forces of nature; an attempt to control the lived environment. For centuries now, we have tried to make day out of night.

First attempts towards some sort of public lighting can be seen in Paris during the 14th century, when the people of the city were ordered to hang lanterns from their houses so to provide light on the streets.

Soon this responsibility was taken up by the administration and later by the police. Light during the night came to be seen as a symbol of authority and order in the city. Public lighting had been recognized as an important tool in policing public space.

The changes in society from a more agrarian, working culture to a manufacturing based, brought about a fundamental shift in the rhythms of daily lifestyle of the people. More and more people started to work in manufacturing and production units, with long working hours.

Artificial lighting extended the working hours beyond daytime and also extended normal day time activities well into the night. Mealtimes, scheduled closure of city gates, beginning of theatrical performances, balls, closing time of taverns moved ever later into the night. Coffee, tea and chocolate became popular and coffee houses opened in all European cities. Pleasure gardens and Vauxhall Garden are examples of extending day time activities into the night.

The development of public street lighting was fundamental to the adjustment of the age-old rhythms of daily life. No European city had permanently illuminated streets until 1660 but around the turn of the 18:th century most of the major European cities had established street lighting systems.

The first cities to establish street lighting

The first cities to establish public street lighting were Paris (1667) and Amsterdam (1669), followed by Hamburg (1673), Turin (1675), Berlin (1682), Copenhagen (1683), London (1684), Vienna (1688), Hannover (1690), Dublin (1697) and Leipzig (1701), illustrating the changing set of relations between the rulers, city and its citizens.

In each city, the lighting demarcated a large and consistent space that was accessible to the general public well after sunset. For the first time lighting was moving from a purely functional sphere to more aesthetic, design and decorative realms. Public spaces, market squares and gardens were being identified and signified by using lighting in these areas.

Certain parts of the cities were being transformed into showcasing the power and wealth of the rulers. The aim was not only to increase safety but also to present the wealth and virtue of their city.

Public lighting could be envisaged for the first time. At the same time, the gas lamp made it possible to have street lighting without attendances, the gas flame burned without cutting and cleaning of the wicks.

Many have called this a change in *culture of illumination*. The warmth and intimacy of the flame and candle gave way to the unprecedented brightness, pipes, valves and glass-protected flame.

It is interesting to observe the evolution of the function of public lighting at night. Prior to the 17th century, lighting was solely an aspect of night watch and policing. Anyone after dark was required to carry a torch or lantern. Not to see, but to be seen.

Failure to illuminate oneself was considered evidence of negative intentions. The new public lighting of the 17th century, in addition to law and order, also attempted and aimed at the beautification and decoration of the city and provided convenience and social amenity by encouraging activities and traffic on the city streets and squares.

The hours from dusk to dawn were no longer seen as threatening time of criminal or illicit activity or supernatural danger; citizens began using night for respectable leisure and social activities.

The Electrical Revolution

The other major revolution in urban lighting was brought about by the discovery of electricity. Electricity from the moment of its discovery has managed to stir the human imagination, like no other discovery before.

The industrial and modern age is characterised by the introduction of electricity into industry, production and manufacturing along with the use in transportation system and electrical grid networks for public spaces and private houses. The quality to convert night into day at the flick of a switch offered the most striking proof of the superiority of the modern over the past.

Electric lighting granted far greater level of control than had the gas lamps that required manual lighting and extinguishment. The ability to automate and co-ordinate a range of actions from a distance created the possibility of bringing rapid changes in lighting. Electricity in general had entered each and every aspect of the industrialised culture.

Electrification took the distancing of lighting techniques one step further by removing the new source of light, not only from the private home but also from the city. As electricity could travel far distances, electricity generation and distribution could be moved to the periphery of the urban centres.

Transformation of the Urban Landscape

The evolution from the trade and agricultural based society to an industrialised, manufacturing and production-based society had a profound affect on the urban landscape as well.

New functions of manufacturing and production required the factories to operate longer and independent to the duration of the day. This had a two fold affect, firstly, as the production methods were labour intensive, more and more people were required in the factories, resulting in the displacement of large number of labourers and their families to the cities. Secondly, the long operating times led to the requirement of shift work that resulted in mass movement of people between the place of work and home.

This led to the development of the first transit systems, first by personal means, that is on foot, and then by public transportation. Such a mass movement of people between their homes and place of work gave rise to the need for public lighting that not only assisted in the fast movement of people, but also provided safe conditions for the transit.

The invention of cars made it possible to cover large distances in small amount of time, further expanding the cities. It became possible to live and work in places far away from each other. The distances between the places of work, living, shopping, leisure etc. increased substantially.

The emphasis of motorised traffic can be clearly seen also in many of the standards around the world that classify public lighting on the basis of the speed of the traffic.

Electrical light and advertising

The new technological advances made electrical lighting brighter, cleaner and safer than the old systems. Electric light started to attract large crowds and inspired many entrepreneurs and businessmen to install electrical lighting as a novel form of advertising. Particularly around city centre, theatre and department stores.

This resulted in more and more light, with business realising light as a potent tool for advertising, dramatizing once sector at the expense of the other. Shop windows and theatres were at the forefront in testing, adapting and utilising new technologies in order to attract consumers.

The increasing competition in advertising and marketing prompted an unparalleled demand for electricity. The increasing demand was being met with ample supply, resulting in cheap availability of electricity. The users were loosing track of the consumption and also of the price of light. This resulted in light becoming omnipresent even during the night time. Darkness and dark areas started to represent under development or unsafe environments and light came to be associated with economic development, activity, safety etc.

Urban lighting experiments

The first systematic explorations of the possibilities for using light to alter the appearance and ambience of urban space occurred in the controlled environments of the world fairs. Creating a time based spectacle for a mass audience. The world fairs showcased the potential for lighting to establish a new rhetoric of urban space, opening the way for the city to be transformed into a performance space.

The trade fair grounds saw new and unique ways of utilising light in public environments. Outlining structures, highlighting pathways, illuminating fountains and probing the applications of light at night.

The trade fairs not only showcased the pioneering and future technologies, but also brought forward the potential of using light in creating urban spaces and the ability of light in manipulating and transforming these urban spaces. The trade fairs were no doubt places for extravagance and performance, but the technology being used for such a spectacle started to migrate to the reality of cities.

Architectural lighting

An interesting phase can be seen in the development of public lighting, in which the facades were utilised to provide public lighting. Light started to be used to highlight or accentuate the architectural details, representing the buildings as a collection of various independent components and details, or alternatively, representing the building as an abstract sculpture standing out in the surrounding darkness.

The new buildings through the use of state of the art building design were seen as symbols of power and economic development, this symbolism was further emphasised by completely illuminating the buildings.

The spread of electrical lighting over the entire cityscape saw a simultaneous rise in new modes of rapid transit systems and the proliferation of glass architecture. This fusion of light, highly reflective surfaces and mechanised movement became the hallmark of the modern city, establishing new spatial experiences, transforming buildings into luminous sculptures.

The experience of the modern city seen at night under electric lights conferred a novel sense of mutability on the previously immutable ad monumental, converting the static historically associated with architecture into a play of dynamic surfaces and seemingly plastic forms.

Electric street lighting and commercial illuminations in urban spaces were complemented by the lightness of the modern architectural style that transformed buildings into luminous sculptures. Buildings were no longer dark structures disappearing in the night sky, but massive light beacons, with light pouring out of the windows and the glass facades.

The present scenario

Compared to the development and relationship between natural light and society, artificial light development has been rapid and swift. Artificial light is now seen as an independent element or object that can be used to manipulate not only architectural volumes and spaces but also emotional, physical and psychological state of humans. Light has changed our understanding and perception of places, shifting boundaries and creating new scale and dimensions. Public lighting has made it possible to extend the activities into the night, increasing the time for consumption and leisure.

Technology has offered the possibility to illuminate anything, any space, any time and anywhere. We find ourselves now in a situation where light is present everywhere and any absence of light is seen as a sign of underdevelopment or is associated with negative connotations.

Uniformity in light levels has emerged as a leading criteria of design and is also reflected in the standards and regulations issued by the authorities.

Lighting technology has been developed that could provide stable lighting with uniform light levels. All the efforts have been focussed on achieving a very limited set of objectives.

The emergence of energy efficiency and sustainability has created a completely new set of requirements from lighting technology. The situation now is that the lighting is no longer of good quality. It is suffering from poor colour rendering and lack of possibilities to control its different parameters. The

current lighting technologies create poor visual environments and visual discomfort. Incorporating such technologies in urban and public lighting solutions eventually leads to false efficiencies and unsustainable practices.

Light Festivals

Urban lighting has entered a new stage in the last few decades. Light festivals or events celebrating light in the urban landscape are emerging in many cities around the world. Festivals and temporary illuminations not only drive visitors to the urban sites of illumination, bringing welcome change to the urban environment, they also highlight special occasions. These festivals are usually temporary in nature but serve the purpose of driving attention to the cities' unique qualities and assets, economic potential and also the problems faced by the city.

These projects often give clues to new potentials and new ways of illuminating urban spaces at night. And many a times the strategies and technologies involved can be transferred to the urban lighting.

There is also an increasing trend towards using light for creating specific images and defining a sense of place. Light is not only a tool for communication and interaction but also a powerful tool to create certain atmosphere. The visual environment is the chief parameter in any given space.

The potential of light to attract attention and direct movement makes it a potent tool in urban design. Places like Times Square in New York, Piccadilly Circus in London or Potsdamer Platz in Berlin are very good examples of light being used to define a place.

Temporal and spatial transformation

The traditional function and image of an urban landscape as a stable and constant ground is giving way to a growing mutability of functions and fluidity of forms.

The modern technologies are contributing in the emergence of a new environment characterised by *relational space*, overlapping both tangible and intangible spaces. Space is increasingly experienced as a relative rather than absolute value. Light on the other hand contributes to the enactment and reproduction of spatial rules by conveying a sense of place.

Light sets people in motion, creating new time-spaces of visibility and thus enhancing the level of communication as well as the fluidity of urban spaces.

Light as a medium, provides a resource that facilitates on-going processes of urban space formation and fusion of time and place. However, it also takes an active part in place-making by imposing rhythms, meanings and atmospheres on urban spaces, by organising space in time, thus enabling or impeding activities and also ways of perception.

New technologies are continuously changing. All daily activities can today be done online through the use of internet, creating scenarios never experienced in urban settings. The traditional function of the city is being redefined; new spatial organisations are emerging based on the personal habits, working conditions and social interactions.

New Requirements of the Future

PHYSICAL AND SOCIO-CULTURAL STRUCTURE OF CITIES HAS UNDERGONE considerable change, that is clearly evident in the physical shaping of the streets and public spaces. As our built environment and architecture becomes increasingly ephemeral, the same is being experienced in the public spaces. Urban areas are increasingly experienced as a relative rather than an absolute value. The definitions of space and distance are being continuously altered.

Further, there is a trend towards the shrinking sense of Public spaces. The city is evolving into increasingly private clusters of loosely connected islands or zones. For example it seems that younger people like to purchase their goods within a five minute walking radius from either the place they live or work or by online shopping. This implies people are spending more and more time in a relatively small area of the city. and.

But also the recent tendency to use shopping blocks, entertainment centres, business parks is changing the scale of the city. Such developments are usually focused inwards, instead of communicating with the public street, activities pouring out onto the open spaces, merchandise and messages to interact with the public space. The public space will be more and more individual. There will also be even bigger changes in function and required atmosphere, then we are used to.

These developments will give rise to flexible and adaptive systems of lighting. Lighting systems that need to respond to the new and unique demands created by urban changes. Need for light is becoming more individualistic, not bound by time or space.

Technology transforms the public space

Changing behaviour instigated by new media, internet, smart phones, online commerce combined with evolving technology and democratisation via affordability leads to a different vision of the use of spaces – whether of a public, commercial or patrimonial nature.

The younger generation today is growing up with a wealth of technology at their disposal, influencing behaviour both private and social in new ways. The convergence of the media and public space is creating new social and economical changes in the urban landscape.

The information technology has added a new dimension to the social behaviour – we are moving away from the collective to the individual and virtual. The individual and *made to measure* customisation are gaining importance. The notion of the network is becoming increasingly present and reinforces the sense of belonging and of recognition.

We are in a world of individualised demands. This customised demand is now finding its way also into the public realm; spaces are being customised to meet the expectations of individuals. Soon we can find ourselves in situations where each and every user would like to personalise the public space around them, create tailor made visual environments to suit their needs and tastes.

Information is continuously being exchanged between electronic devices. All the devices we have surrounded ourselves with today can in fact be used to predict our needs, likes, dislikes, taste, behaviour and even fears. Such information can be vital in creating public spaces and visual environments, that despite of being based on individual demands, can serve the public as a whole, bring order through chaos. Such systems could also help predict lighting requirements and need for flexibility and multi-functional lighting.

But in addition to that, public lighting is still a potent tool in establishing the functional and visual hierarchy in a city. Artificial Light is the most essential component in establishing a visual organization in a city during the dark and it is imperative that the function, needs, aspirations of the end users are not overlooked in establishing any sort of visual organizations.

The challenge of fulfilling these ever evolving requirements can be made possible by the technological possibilities offered by LED and can provide tools to design for such urban environments.

Evolving Lifestyles changing the public lighting

The technological revolution has brought about a shift in lifestyle. We are constantly connected to the entire world through electronic devices. This has resulted in a shrinking world, where physical distances are no longer significant. Technology has broken boundaries of time, distance and space.

The very purpose for public lighting is being transformed because of these changes, the need for functional lighting to get from point A to point B, will be replaced by the need to have the right quality of light for social interaction, entertainment, exchange and also awareness.

Dark hours are emerging as the main part of the day, concentrating many of our activities. People are going out more at night, they are socializing more in public spaces, thus now more than ever the urban lighting needs to reflect the relationship between the user and the city. We are restructuring our physiologies and values, creating new cultures of public spaces.

Lighting needs to be based on multi-dimensional approach involving people's aspirations, demands, fears and interactions in the public spaces. Apart from the functional requirements, the differences in perception, behaviour patterns, ambience, social context and information, create a set of distinct requirements for public lighting in the future.

A technology such as LED with its unique ability to combine various functions in one source, along with the infinite possibilities to control the quality and quantity of light, can offer possibilities to fulfil these new demands and requirements.

The role of LED towards the sustainable city of the future

The technological advances we have made till today allow us to gather information about our needs and demands. When combined with the new technological possibilities offered by LED, we can truly realise the true potential of such technologies. Control systems can be used to dynamically control the quality of light according to the use, frequency and other parameters.

The control systems can make it possible to reduce the energy consumption without reducing the quality of light. LED technology offers the possibility to design complex control scenarios that can dynamically change the characteristics of light with changing requirements, uses and needs.

We are today developing concepts like carbon neutrality and fundamental to such carbon neutral concept is the reduction in the energy requirements of the city.

LED technology comprise in itself only a part of the solution, a simple replacement of old technology with new technology is again looking at only short term goals and missing the bigger picture.

A simple application of dynamic lighting control is the control of illumination levels based on the user frequency. A further extension could be the integration of other sensors like proximity, user intensity, weather and climate sensors, these sensors in turn could control parameters like brightness, contrast, light colour etc.

Also when not enough energy is available, there could be for a short time low light levels as we would be working with renewable sources of energy,

Functions that earlier could not have been controlled like light distribution, colour rendering can now be controlled with the use of LED technology. This allows for the optimum design for each use or function with the appropriate light quality, maximising the energy saving potential.

LED helps to have positive influence on social behaviour

In the last few years, we have witnessed unprecedented violence in many urban cities around the world. It might be very easy to put blame on few particular groups or individuals, but such acts of violence raise questions about the social systems we are living in today. What are the reasons behind such a deplorable social behaviour?

The built environment we live in has a great influence on our personal and social behaviour. Light is also a component of this built environment, and that too a very crucial component. Light enables us to

see the world around and experience it. A positive visual environment is bound to have a positive influence on our social behaviour. Moreover, the involvement of the local community has been proven to reduce levels of vandalism and crime.

Efforts should be made to create a quality and positive social and cultural infrastructure, as this is essential in fostering a sense of identity and belonging in a community. Social interactions enable participants to act together more effectively to pursue shared objective, like lowering crime rate, less filth, better education and better health.

LED will allow reacting on special user needs

In a recent study it has been found that elderly people require more light during the night for the same functions compared to younger or middle aged people. Additionally, experimental findings also reveal that in a given lighting situation, in general men felt safer than women. These studies indicate that elderly and women require higher light levels to improve their feeling of safety.

Similarly people with some sort of visual impairment would also require higher light levels to perform the same functions as an individual with normal visual abilities.

The public and urban lighting currently does not take into consideration these special needs and requirements. Mainly due to the fact that the conventional lighting technology does not offer the possibility to adapt to such needs.

However, LED technology does offer such possibilities, in a simple example communities with a larger elderly populations could have higher light levels for better orientation and facial recognition.

The public lighting in such areas could be with certain markers or way finders so that the people can easily orient themselves and identify their position.

LED provides synergistic benefits

Synergy is the combined power of a group of things when working together creates a result greater than the total power achieved by each working separately. The goal of having a zero carbon city can only be achieved when the different infrastructural, social and public services work in complete harmony and coordination.

When this concept is applied to services like traffic regulation, with the use of frequency and intensity sensors, street and public lighting can be dimmed to minimum levels during periods of decreased or low traffic movements, saving on energy demands.

Similarly, in cases of medical or police emergencies, lighting levels, colour-rendering qualities could be increased to assist quick action and response.

Essential social services like important announcements and information can be transmitted through the public lighting system. CCTV cameras and emergency services can be easily integrated and the public lighting can be programmed to respond to such situations. Public lighting can form an important link between the various other services and infrastructural activities in a city.

Urban Regeneration

A city is a complex, dynamic space produced through the interaction of the built environment, open spaces, light and movement.

Lighting along with other urban design strategies is being used as a tool for urban regeneration. The city of the future has to grow as a singular entity; the future city cannot have concentrations of development while the rest of the areas in the city suffer from poverty, marginality, ignorance and exploitation. Taking into account the potential impact of lighting on our bodies, behaviour and social interaction, it can be assumed that illuminating urban spaces differs significantly from other means of urban renewal, such as new paving or street furniture.

Effective urban lighting can provide safer cities, highlight national monuments and landmarks, create beautiful and stimulation sights and give boost to the nighttime economy.

Part two
LED-lighting, what is it?

LED-lighting – How To See It and How To Regard It

IN THE FOLLOWING ARTICLES WE WILL DISCUSS LED LIGHTING IN THE CONTEXT of urban lighting. Having said that it's first of all neccessary to put the needs and requirements of the user up front. Decisive factor for the design of a lighting installation is not only the location but also the kind of people who use the installation and their different intentions to use a space. The variety of user demands can be wide, depending on the users and their intentions, as for different times of the day and for different user groups, the lighting demands depend on the surrounding environment. LEDs provide a uniform illumination and this makes them suitable for more applications in the urban environment.

LED technology can lead to a balanced result of a functional lighting installation and a beautiful attracting place. The current lighting technologies using the conventional light sources offer a limited variety of design tools. LED as light source gives a great amount of possibilities to designers to create a variety of luminaires with different light distributions and light effects. LED lighting has a white light of high quality. The emitting light has great colour rendering enhancing the perception of the surroundings.

Moreover, LED lighting solutions are energy efficient and sustainable, respecting the environment and the dark sky of night time. Control systems offer a great possibility to control the led installations based on different factors or scenarios, such as the traffic volume, the amount of the users, the presence or not of a user, seasonal change, etc.

The current LED equipment's energy consumption is much lower comparing to the old lighting sources. They are long lasting having a lifetime that leads to less replacements of equipment, so to a lower maintenance cost.

It is presenting an analysis of existing standards for urban lighting and recommendations of new ones focusing on user's needs and not on LED as product.

Finally, it is pointed out the importance of guides and planning tools in order to achieve a high level of communication between the involved partners and create a common basis/process for all.

Lighting is a tool that can help planners and designers to enhance the structure of the city, pointing out the different activities in different public spaces, creating an environment that fits to user's needs. However, the continuous progress and update of LED technology make the municipalities still think of it and delay the installation of new equipment. Moreover, it is a sustainable solution and also reduces the impact of human on the environment.

The analysis of the existing standards, the new technology and the possibilities it offers lead to a point that the need for reviewing standards and expanded approaches is imperative.

There are rules for the amount of light that is appropriate, but there is not recommendation for the architectural part of the installation. It is really important to establish not only quantitative but also qualitative standards for LED technology based on good lighting conditions for the user.

Proposals of new fields and recommendations for new standards must be done focusing on user's needs and not only LED as product. New techniques, according to which new understandings could be created, must be established.

The location, the kind of use, the group of users, all stand for certain necessities or user demands which needs to be regarding during the planning of a lighting installation. LED technology supports a great variety of fixtures and lighting equipment that can fulfil different concepts.

Finally, the right communication of the ideas among the involved partners during the whole process and planning is significantly important. Guides and planning tools would help all municipalities and authorities to develop Lighting Master plans for urban areas in collaboration with professional lighting designers and engineers involving also the general public in the design process.

Product Abilities

LED:S EMIT LIGHT FROM FINITE SIZE SOLID BODY, SO THEY CANNOT BE REGARDED as point light sources which light directivity diagram is spherical. Needed light distribution is obtained by using means like lenses, reflectors or arranging LED:s in correct practical way. Working principle of lenses is based on refraction of light. During the production of LED:s above the radiator usually are formed lens, which not only strengthens the design of LED:s, but also enhances the light transmission to the environment.

To achieve required luminous flux parameters secondary optics is used, such as the lens, which is installed above of LED:s lens. Currently, a wide range of lenses by the formation of the flux angle is produced: from narrow (<7 °) to large (180 °) beam. In addition, the lenses can change the form of luminous flux, for instance the ellipse or ring shape.

Reflector reflects LED:s light from reflecting surface. The reflector that is mounted above LED is made of plastic or metal casing with specially shaped work surface covered with reflective material, for example plastic with metalized surfaces.

It is possible to achieve the desired light output distribution by changing layout of LED:s. The application of this approach to the management of traffic lights is also included in the technology – lenses and / or reflectors.

An additional way to form the desired lamp luminous flux distribution function is to allocate LED:s distributed on the surface of a special form. If fixtures consist of an array of lower power LED:s compared with the same power lamp with of one or more LED:s then much less glare and lighting is more even.

Colour

White light LED:s are characterized by two parameters: correlated colour temperature CCT and colour rendering index CRI (Ra). Colour temperature is a simplified way to describe the spectral properties of the light source. Low colour temperature LED:s will spread slightly “warmer” light and high temperature consequently spread cooler light.

The colour-rendering index of a light source is a measured by how much test colours perceptually shifts when viewed under the light source in comparison to a reference light source with same colour temperature. However, the light source with lower CRI does not necessarily mean it has poorer colour rendering. There are already proposals to change the CRI to a better system.

Currently in the market white light LED:s are used to obtain white light: LED:s coated with phosphor and polychromatic LED:s. Better colour rendering is generated using phosphors of several colours. In polychromatic LED:s white light is obtained by mixing different colours of light. In LED body there are mounted two, three or four light emitting crystals with different colour of emitting light. The most common LED:s have three RGB colours. Better colour rendering is achieved using four-color RGBA LED:s.

Control

LED:s light in the operating mode is characterized by electric current that flows through it and voltage drop when appropriate voltage is reached, LED:s will emit light and degree of current-voltage dependence of LED significantly changes. Current variation is very high. LED:s luminous flux is proportional to a current that flows through it, so in order to obtain constant luminous flux of LED:s the current is stabilized by passive or active current control methods.

Dimming LED lamp (reducing LED:s luminous flux) is achieved by reducing the current. However, the most commonly Pulse Width Modulation (PWM) method is used: at a frequency at which people do not notice change of luminous flux, current of LED:s is interrupted. When current interruption time is increased, the LED lamp is dimmed.

LED lamps are controlled in several ways: by dimmer changing LED lamp supply voltage and communicating with LED lamp trough communication channel. LED lamps must be specially designed to enable their control by changing their supply voltage: they react to the curve of supply voltage that is formed by dimmer. Usually these LED lamps are an alternative for incandescent bulbs, which are controlled with a dimmer switch.

LED fixture that supports the communication link has greater possibilities: it is possible to change several settings in the fixture - the total luminous flux of light and light. It enables to check the efficiency parameters of lamp etc. Communication channels are of different types: wired – by connecting LED lamps to communication cable and using Power Line Communication; or wireless – by radio waves and optical (infrared) link.

By combining LED lamps in to common group a Grid Control is created. According to the size of the Control Grid it can be divided in to: large Control Grid – for City and small Control Grid – for Home or Office.

Energy Efficiency

As it is known, LED converts electrical power into light. Conversion circuit consists of the following components: power supply; LED; secondary optics; reflectors (if applicable). All these components produce an inevitable loss of energy. To improve energy efficiency of LED lamp the amount of energy loss should be reduced.

LED:s cannot be connected directly to the power supply network, because otherwise, the LED:s will be overloaded, resulting reduction of working time or it will fail immediately, or it will not be fully exploited. Thus, in order LED:s to operate in manufacturer's recommended mode, LED:s must be fed through a power source converter. Power supply units are not ideal due to the loss of power. The power loss of passive power supply unit is mainly in resistive ballasts, where electrical energy is converted to heat.

If the LED lamp is designed to work with AC power supply, the efficiency of power source is increased by using reactive ballasts. Unfortunately, increasing the efficiency of the LED lamp reduces its power factor, which is improved by using the Power Factor Correction circuits.

Using switching power supplies increases efficiency of LED lamp. In these active power sources the quenching of electrical power is not used, leading to their higher efficiency. Currently, in LED luminaires the efficiency of switching power supply is about 85%.

One of the factors influencing the efficiency of LED:s – LED:s temperature: when rising temperature efficiency of LED decreases. In addition, the temperature changes colour of the light emitted by LED:s crystal, properties of phosphorus, leading to changes in spectrum of light emitted by the LED lamp. These problems are dealt with transferring heat from the LED:s to the heat sinks using the electronic control means.

The last element on the way of conversion electricity to light, which determines the final LED fixture efficiency, is a secondary optics. How efficient LED:s light will be emitted to the end user depends on how light will be collected by optics, how the light will be focused on the target. Also the transparency of lenses should be considered. Improving the utilization efficiency can increase LED lighting efficiency. For this purpose, Smart Lighting is used: LED is switched on/off or changes its luminous flux depending on the current environmental situation.

Luminaire life claims

Luminaire life time depends on the reliability of the components of an LED luminaire as a system, including the electronics, materials, housing, wiring, connectors, seals, and so on. The entire system lasts only as long as the critical component with the shortest life, whether that critical component is a weather seal, an optical element, an LED, an electronic control gear circuit or something else. From this point of view, LED's are simply one critical component among many — although they are often the most reliable component in the whole lighting system.

Conclusions

There is also a scope of new arising technologies for the future lighting system applications, which might become a reality in a short period of time and the market and consumer. There is an ability to raise the knowledge and awareness of people using schools, colleges, and universities.

There is still a lack of information and practice of high power LED systems reliability and this situation is a drawback for creating standards related to the reliability of LED luminaries systems. LED at most times are the most reliable features of the system, so the other parts like control gear, heat sink, insulations, welding and soldering joints are to be strictly regulated. The designers still hasn't used in full flexibility range of LED lighting systems.

The lobbying issue should be directed to these institutions: ministries that are responsible for the electrical power consumptions, responsible for the environmental issues, universities, schools, media, and local municipalities. Manufacturers are the first which are showing the most interest in the quick standard development (organizations like CELMA).

Features to be addressed in the new standards would be: power factor control, reliability, colour rendering, glare, luminous flux, colour temperature, stable luminous flux during temperature change; heat distributions and maybe regeneration, efficient spatial LED distribution, diffusers, reflectors.

This artificial light source in the future might be using such techniques: Fully controlled light source; LED:s; OLED:s; LET:s – light emitting transistors; OLETS – organic light emitting transistors; Usage of renewable energy source for light emitting element to produce the light; Bioluminescence; Light storage; AC LED:s; MEMS – microelectronic mechanical systems to control shape of luminaire; NEMS – nanoelectronic mechanical systems to control shape of luminaire; Smart reaction to human's emotions.

From all these above mentioned techniques, only fully controlled light source, LED:s and usage of renewable energy source for light emitting element to produce the light are well developed for controllable light source and the standardization of these features are the main goal of the standard organizations and manufacturers.

User Needs and Demands

LIGHT IS ESSENTIAL FOR THE VISUAL PERCEPTION OF A CITY AND INDISPENSABLE physical input for the user. Through vision we receive important information about our surroundings. Each and every user or individual will exhibit a unique set of needs, demands, activities, behaviours and perception.
An urban landscape is made up of a vibrant mix of various urban settings, activities and events; generating very specific requirements and demands. Urban lighting has to not only address these requirements but also has to shape the relationship between the inhabitants and the urban space. The function based approach to urban lighting needs to be transformed into a multidisciplinary approach, using principles of social sustainability, perception and behavioural patterns, human psychology and environment.

There can be a number of ways to differentiate between the various needs and demands of the user; one of them is based on the speed of movement:

a. Pedestrian movement / Slow movement.
b. Motorised movement.

In a typical pedestrian environment, in general, there will be a need for:

1. Safe movement.
2. Visual orientation.
3. Visual comfort.
4. Facial recognition.
5. General feeling of safety.

The visual content along with the space, architecture, activity, sound and light effects the pedestrian environment, and in turn the pedestrian environment thus created will generate its own distinct needs and demands. The final cumulative effect of all these factors eventually affects the pedestrian behaviour and quality of urban space.

Light levels, uniformity, contrast, distribution, and visual size and glare all affect visibility. The information perceived through these characteristics of light is codified and interpreted by the human mind as the perception of the urban environment.

Some of the properties mentioned above are directly governed by the light distribution characteristics of the lighting systems. The small size of the LED light sources offers the possibility to design lenses and optic systems to create light distribution as per the needs and requirements and also creating clear distinctions between horizontal, vertical and semi cylindrical illumination. With LED:s the light distributions can be designed to have the optimum light qualities to create rich and unique visual environments.

Feeling of Safety

There are still questions over the theory that light can reduce crime and increase the feeling of safety.

Facial recognition is a key element in the feeling of safety at night. People tend to feel safer in cases where they are able to see their surroundings clearly and well in time, they are able to judge a space or situation as safe or unsafe, thereby increasing their feeling of security.

Light in urban setting needs to make places visible, legible and understandable, to increase the feeling of safety, facilitates orientation and the understanding of functions .

Visual Cues

The human mind scans the surroundings for an overall view of the surroundings, searching for visual cues to develop a mental image of the surroundings.

Light accents, for example, the illumination of specific design features, monuments, landmarks, architectural elements, fountains and trees create visual stimuli. This helps in recognising the surround-

ing spaces and also creating an identity. Light accents also indicate the depth of a space, further enhancing the overall view of the surrounding and providing visual orientation. Such visual cues help the individual to recognise their location in terms of the city and assist them in finding their destination.

Glare

Glare can be defined as partial or temporary difficulty in viewing. Glare occurs whenever one part of the luminous field is much brighter than the general brightness of the luminous field. Since during the dark hours, the overall brightness of the luminous filed is generally low, any source of artificial light is a potential source of glare.

Light distribution and light direction can be precisely controlled using LED light sources using lenses, optics and reflector systems. This quality can then be used to control illumination of various elements, creating a luminance field that is balanced and does not create large discomfort glare, thus can assist in visual adoption.

Safe movement

One more key role of urban lighting is to ensure the safe movement of both pedestrian/ slow traffic and motorised traffic. This role is amplified at the points of intersection and conflicts between the different movements.

A visual environment that ensures visual comfort, appropriate contrast and brightness ratios, low glare and colour contrasts is essential for the motorised traffic to see the pedestrian traffic and vice versa.

The LED makes it possible to design customised light distribution systems that can create the optimum visual environment, bringing light to where it is most required and essential.

Visual Adoption

Brightness and distribution of light are amongst the most important factors affecting the visual perception of a space. Moreover, surrounding brightness and higher contrasts make visual adoption difficult this can affect the feeling of safety. Brightness and luminous contrasts need to be adjusted to the surrounding brightness to provide an overall view of the surroundings and reducing sharp contrasts in the visual field.

LED technology with its distinct property of being able to be dimmed from 0-100 % offers innumerable possibilities and applications in public lighting. The lumen output of not only the complete luminaire can be controlled but the lumen output of each and every LED can be controlled.

White Light: Improved Spectral Power Distribution

It has been observed that white light along with good colour rendition assists in facial and colour recognition at lower light levels than the light levels required with low colour rendition light sources, resulting in lower overall light levels, that ultimately results in lower energy requirements.

Encouraging sustainable and healthier lifestyles

Light apart from the role it plays in stimulating our primary sense of vision, has far more reaching effects on human physiology, psychology and human behaviour. These human traits then eventually affect the social behaviour, shaping and forming the society of today.

Lighting can play a significant part in reshaping and creating new lifestyles and habits that promote a healthier and sustainable living.

Lighting can also be used to discourage the use of motor vehicle and encourage pedestrian and bicycle movement. Public lighting can be used to encourage more nighttime interactions.

LED in Urban Context

NOWADAYS THERE IS A VERY DIVERSE AND RICH MIX OF URBAN LANDSCAPES. Cities are being transformed into a complex and extensive network of interwoven threads of varying political, economical and social environments. The city is experienced as a complex, dynamic space produced through the interaction of movement and light, moving from one visual field to another, turning the city into a landscape of shifting light intensities .

Kevin Lynch in his book *The image of a city* identifies certain key elements of an urban landscape, namely, paths, nodes, district, edges and landmarks. These elements help in understanding the composition of a city by structuring the various elements of a city and creating different zones within a city. This in turn gives rise to an organisation of space and eventually establishing a hierarchy.

The fundamental component of any urban landscape is still the user; urban lighting has to meet the needs of the user and has to ensure that it serves its intended function.

Taking this as a starting point public lighting needs to incorporate the following features:

- Orientation.
- Aesthetic.
- Identification.
- Structure and Design.

Public lighting needs to establish and create environments with:

a. Sense of security.
b. Sense of direction.
c. Sense of scale.
d. Sense of play.
e. Sense of participation.
f. Sense of value.

Built environments with these qualities will create spaces that have sense of proportionality, reality and identity and at the same time are safe.

Multi-functional lighting

Public lighting for the first time will be able to respond to even hourly changes in uses and not only long term changes. A single luminaire can provide solutions for various functions, for example a busy commercial area can have office spaces, restaurants, eating joints, places to socialise and relax, entertainment and event spaces all compacted into one space. LED technology now allows a single luminaire to provide good quality lighting for all these and many more functions. The small size of the light source makes it possible to have a number of lighting solutions combined into a single luminaire. Solutions can be provided for changing functions, activities, time and seasons or weather; the possibilities are as vast as our imagination. The LED technology will be able to provide lighting that is suitable as well as encouraging for such varying activities and functions.

Readability

Light has the capability to create shape, emotional response even on familiar space through the use of compositions and organisation of lighting elements . Light is the main source of information about the space.

The aim of readability is to guide and govern the public space. Through different measures the user should form a visual impression of the character of the area and the function of the space.

Through the use of varying light distributions, having light on certain elements and controlling the brightness and direction of light, a visual environment can be created that can help in scanning the surroundings, creating an overall view of the surroundings and provide visual cues.

Image of a city

It is the quality of public spaces, the physical and visual environments to evoke a strong sense of representation or remembrance. By creating an image for the environment, the user can very easily locate in the space, and it also positions the user in time, providing an overall sense of historical roots, the present scenarios and the future. At a deeper level it allows the user to attach their own meaning to the city and its parts.

Some of the ways to improve or alter the city's image are to change the physical city by creating new landmarks, or views, restructuring the street system, strengthening weak edges and intensifying district character. But these physical changes to the built environment are extremely intensive resource and time-consuming exercises.

Lighting on the other hand is a simple and much easier way to bring about similar changes and the results can be seen instantly. Light is amongst the best methods of symbolic communication, it works directly with the symbols that make the images of a city and it can very easily alter people's mental image of a place.

Human scale

With the use of conventional light sources, in order to avoid disability glare, it is recommended to have the highest possible mounting positions. This gives rise to solutions that are not optimum and efficient. Firstly, higher wattages and lumen packages are required to bring light to the surface where it is required. Due to the large distance involved between the source and target area there is a lot of obstructive light in terms of spill light, light trespassing and sky glow. In addition, in such solutions, the increase in foliage of trees in the summer causes obstruction of light and unwanted illumination of trees.

Grey Cities

The character, identity, structure and hierarchy a city has by the day are lost by the night, the Sodium vapour lamp has a very low colour rendering index that makes the recognition of materials, textures and colours very difficult.

Using the traditional sodium vapour light sources, a beautiful lively baroque square by the day with authentic material, colours and texture can be transformed into a monotonous, monochromatic space by night; in the process completely altering the perception of the urban space.

Urban Materials

An urban landscape is made up of various elements with varying finishes, textures and colours and also with different shapes, dimensions and proportions. Light interacts with these various elements in distinct ways based on their surface properties and effects our visual perception of the urban landscape.

With the use of control systems and LED lighting technology, it will possible to change the colour temperature of the light, to change the colour of the light along with the possibility to change the direction and intensity of light. These properties can be used to adapt and respond to the different elements in an urban scene based on their colour, texture, finish, size etc.

Daylight availability

Some of the most popular control systems today include the photoelectric cell, used to detect the amount of daylight available; this ensures public lighting is available only when it is necessary. Considering the fact that most conventional public light sources require some amount of time to come up to full light output and also that this results in setting higher levels of daylight availability when the public light switches on. LED:s have a very clear advantage in this respect, they have an instantaneous start and can be started in a dim state and plus they do not show any colour shift at dimmed running state, the daylight levels when public light switches on could be set lower, implying the public lighting will switch on later or will run on dimmed levels during dusk. This will clearly lower the energy consumption during the evening and dusk times.

Direct energy saving potential

LED:s can be easily integrated with lighting control systems that can control light output based on parameters like:

- Traffic Volumes.
- Ambient Brightness.
- Weather conditions.

In addition, adjustment of light levels can contribute to reduction in light pollution and wastage of light. Adding to this the fact that LED technology allows for adjusting parameters like light distribution and light direction makes it possible to bring light to where it is required, how it is required and in what quantity it is required. These qualities of LED make them more energy efficient and further reduce the problems of light wastage, light trespass and light pollution that eventually lead to energy wastage.

The difference in colour perception between LPS (left) and LED (right)

Standard Development for Public Lighting

LIGHTING STANDARDS BASED ON PRINCIPLES OF GOOD LIGHTING, SERVE AS a bridge between lighting engineers, urban designers and planners, landscape architects, lighting designers, technicians, municipalities and lighting quality in Public Spaces.
Lighting designers and engineers can measure the lighting parameters to examine if they agree with the existing standards but these values have to be assessed in terms of to which extent they represent the user's experience.

Based on the surveys of the project and the results of them about the user's needs and demands in different public spaces, this chapter tries to evaluate if the existing standards can support the new technology of LED and propose new fields/values for standardization from the aspect of the final user that is the person that circulates in the urban space, focusing on pedestrian. It may be helpful to consumers, that most of the times are municipalities, enabling them to select the most appropriate product for lighting up a public space.

During daytime, natural light create a secure, safe and comfortable environment for the user. Having in mind this, artificial light has to offer this quality of light during dark hours fulfilling as much as it is possible the needs of the user in each case.

The basis for existing standards, factors and structuring

Lighting standards for pedestrians have been almost a by-product of lighting standards for car traffic. This was happening because it was believed that driving requires a better visual perception of the space than pedestrian needs in order to walk. Thus nowadays, after having realized that the importance of the right lighting in both situations is the same, there is an attempt to understand the differences among drivers and pedestrians and establish new standards that fit in each occasion.

Passing the years, it is becoming clearer that the purpose of public lighting is not only to make streets safe and prevent the crime and road accidents. In the past, there were strictly functional limitations based on technical and economic reasons but nowadays the lighting projects show the change of this attitude.

Light designed for pedestrians

Light is an important part of the city elements in order to have the right circulation during nighttime. People have to feel comfortable when they move in the urban space. A lot of times, footpaths don't have independent light for pedestrians but existing street lighting illuminates them.

So, recommendations could be established in order to create and install specified lighting for pedestrians for every footpath independent from the light installation for the car drivers.

Surroundings

The surroundings are a really important factor as they are connected inseparably with the visibility that the driver or pedestrian has and the security that he feels. It depends on the surrounding environment of the road how lighting designers are going to use the light. When they have to light up a street that passes through buildings in commercial areas, they have to take into consideration all these elements that surround the installation keeping the role of each building and use the light as an additional element. Fenestrations, windows of houses, buildings, windows of shops contribute to the light installation and affect it.

On the other hand, if the street passes through uninhabited areas, not overcrowded, or a park –nat-

ural environment- the light could be used as basic element in order to create an installation that has a character itself, maybe calling people to pass through the space or stay and experience it.

So, recommendations could be adopted about the surroundings that will oblige planners to take into consideration the existing light of the area and deliver calculations taking into account these light levels too. It would be recommended controlled light for roads between buildings or illuminated central streets with shop windows lighting.

Visual Orientation

Sometimes it is difficult for the user to understand the space and react in this. Lighting has to enhance the points where the direction of the user movement changes and make clear the origins and destinations of the paths helping people to perceived from where they come and where they led. Moreover, there are different elements along paths, such as buildings, trees, shop-windows, that can help the user to find the orientation of the area and move easily.'

So, it would be recommended to lighting designers to light up significant structures, buildings, intersections, etc. in order to enhance the perception and orientation of the night-time users.

Architectural aspects

Each area has a unique character and it is important that lighting is designed according to its architecture rather than being standardised. In this case, the objectives of lighting are retention and enhancement of the architecture, historic or landscape character of the area. So, only regulations about the levels of illumination could be followed and not standards about the design process of the light installation.

Safety – Security

One of the most important factors that must be taken into consideration for the formulation of new standards is the safety of the user of a public space. Safe public lighting ensures that pedestrian is able to distinguish obstacles and obstructions without getting injured. Moreover, pedestrian have to be visible to all the other users of the space, such as car drivers, motorist, cyclists and other pedestrians.

Light is one basic element that can enhance the safety and security of a place during night. This doesn't mean that the more light, the safest the place. Lighting designers have to respect the darkness of the nighttime, working a lot with the contrasts and not with the levels of light intensity. Public lighting has to protect pedestrians from being attacked and minimize undesirable antisocial behaviour.

Visibility

Visibility field for pedestrian areas is different than this one of roads for vehicles. Drivers need lighting that will make obstacles visible and allow a quick reaction. For a pedestrian, the demands are the same but now the speed of moving is different. Moreover, in a pedestrian road, it has also to be thought the speed of the user, if it is a running route, stairway, bicycle road, intersections, etc. It must be taken into consideration that the surroundings of a pedestrian road are important for the user comparing to a highway, because it is appropriate to light up also obstacles such as branches side trees, changes of grade, etc. and that most of these tasks need greater ambient illumination.

Pedestrians require lighting to enable visibility and recognition of other persons who are approaching providing the suitable information if the oncoming person is a threat.

Controlling urban light

Public lighting in cities is generally on all night, during the dark hours of the evening. But nowadays, the technology of LED gives the possibility to control the light dynamically. So, it is appropriate in the future, to establish recommendations for the controlling of the public lighting. It could be done based on the time of the day, the season, the traffic intensity, the presence or not of people in pedestrian roads and parks.

For example, more light could be installed when there is more traffic and less when there is less traffic. When busy traffic approaches, more light comes on automatically, and when the frequency of traffic decreases, it decreases again.

Maintenance

Energy efficiency could be connected to the maintenance of the lighting installation. It has to be clear to all involved parts in urban lighting that the right and frequent maintenance and cleaning of the equipment can contribute only positively and profitably. So, standards about the frequency and the way municipalities have to maintain the lighting installations could be established. LED life time and performance is longer comparing to the old light sources, so municipalities could reduce the maintenance cost of the public lighting installations.

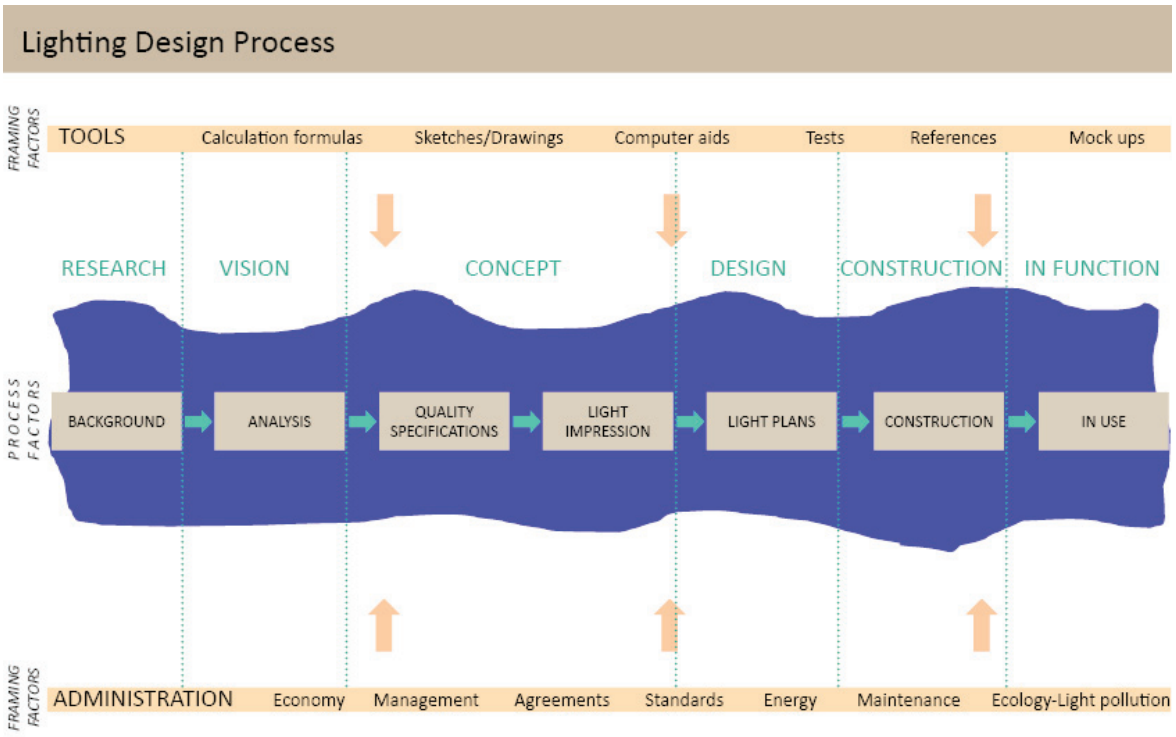
The new technology of LED gives a great variety of design possibilities and light distributions. So, we could create standards that will have a humanistic approach enhancing the perception of the space and serving the needs of user.

The investigations of standards is a really complex process, as standardization is a dynamic process and standards have to be updated as there is a continuous development and progress of new technologies and in our case the technology of LED. So, it is essential all the organizations and institutions that are involved in the field of lighting and standardization to take discussions also with users, municipalities, lighting designers and engineers and not only with manufacturers, in order to deliver standards that guarantee light of great quality in public spaces.

To sum up, lighting standards could focus on:

- User's needs and demands (unprotected, road-user, pedestrian, cyclist, motor-bikers, etc.).
- Context of the surroundings.
- Dynamic light (adapted to local conditions and functions, frequencies, time of the day, seasons, etc.).

Further, they should be based on lighting qualities like distribution, brightness, colour rendering, CRI, colour temperature and uniformity-variation (related to the speed and the site).



What happens in the design process between identifying a problem and reaching a solution.
Diagram- Source: Jan Ejhed, Metoder för belysningsplanering, KTH Arkitektur, 1981, Stockholm

Planning Tools for Public Lighting

THE OBJECTIVE OF A GUIDE/PLANNING TOOLS IS TO GIVE THE SAME BASIS AND STAGES of design and planning to all the involved partners in the working groups, urban planners, architects, lighting designers, engineers, technicians, municipalities, stake holders, etc. in order to follow a common line delivering the best result. All this design process even if the above schematic sketch shows it linear, in practice it is not. Irather loops back to itself when all these interactive framing factors are taken into consideration during the planning.

The design process helps the team of lighting designers:

- To analyse the problem
- To communicate and share their ideas
- To give structure to their thoughts
- To get to a solution in an established time

The description of a design process is an instrument for designers can communicate and share their ideas with their colleagues or clients.

Light impression

When designers are working on a project, they think primary about the light shapes, forms, feelings, contrasts that they want to create in the certain place and then they are trying to materialize it with luminaires, lamps, equipment.

Use the light as complement or as element

In the design process, the light can be used as complement, related to other structures and existing potentials trying to reveal, support, enhance the existing situation. It can also be applied to hide various elements of a construction. It is a tool for a neutral description of the physical environment, enabling the nocturnal image of existing elements (for example: lighting up of a sculpture).

On the other hand, when light is used as element means that light has the 'first role' in our place. They use the light, for example, to create a light landmark in an empty spot and not light up a sculpture to create a landmark. Designers use the light with a more artistic approach, enhancing place's attraction and identity, in order to call people and experience the place.

Lighting Masterplans

Since public lighting is an integral part of urban planning, an overall lighting masterplan will identify and bring to focus the various elements in a city and how they can be brought together to better understand the city. The lighting masterplan is not only essential for the readability of a city but also to develop the sustainability targets of the city. A lighting masterplan can help in establishing targets and guidelines for achieving social sustainability along with environmental and economic sustainability.

The lighting masterplan illustrates the concept for the space/area that it is going to be lit. It is a way by which lighting designers and planners communicate their ideas to the other involved partners and the discussion on the project is taken place easier and more understandable based on drawing and diagrams.

Masterplanning Urban Lighting is a comprehensive concept that considers the urban nightscape in all its aspects. It starts with safety and security and moves on to the forming of the objective impressions of all the various visual components of both residents and visitors that help to ensure an attractive, commercially successful and energy efficient night-time economy.

Monitoring

There is an increasing trend towards monitoring, especially remote monitoring of the public lighting luminaires. Such monitoring of each luminaire allows faults, failures, operating hours, wasteful operation to be identified and rectified quickly. These results can be used to plan maintenance schedules, analysing energy consumption patterns. Such measures ensure energy saving by controlling light when, where and how it is needed but also helps in establishing a better quality of urban life that responds and reacts to the need of the society.

Dynamic control of light

Significantly more energy can be saved in a lighting installation, when it is operated by an intelligent lighting control system. A lighting control strategy is very beneficial in saving energy as light is utilised only when it is required. But an urban setting with people is rarely a static situation, it changes and transforms with the changing needs and demands of the people. Technology for the first time offers the possibility and the tools to have a dynamic control system that can react and respond to the changing requirements. It is exactly this point where we can have the maximum energy saving potential. There is now the possibility to adjust the amount of light according to:

- Traffic volumes and flow.
- Ambient brightness.
- Weather conditions.
- Visibility conditions

Lighting Maintenance

Lighting designers usually provide initially an illuminance above the minimum light level to compensate the lighting loss through the time. The light levels start gradually to decrease due to various aging factors. A way to achieve keeping the highest amount of light from the installation is to maintain the

whole installation by a predetermined maintenance program. Lighting maintenance consists of replacing and cleaning of luminaires at planned intervals. By such programs, municipalities can save money and conserve an installation of high performance for longer time.

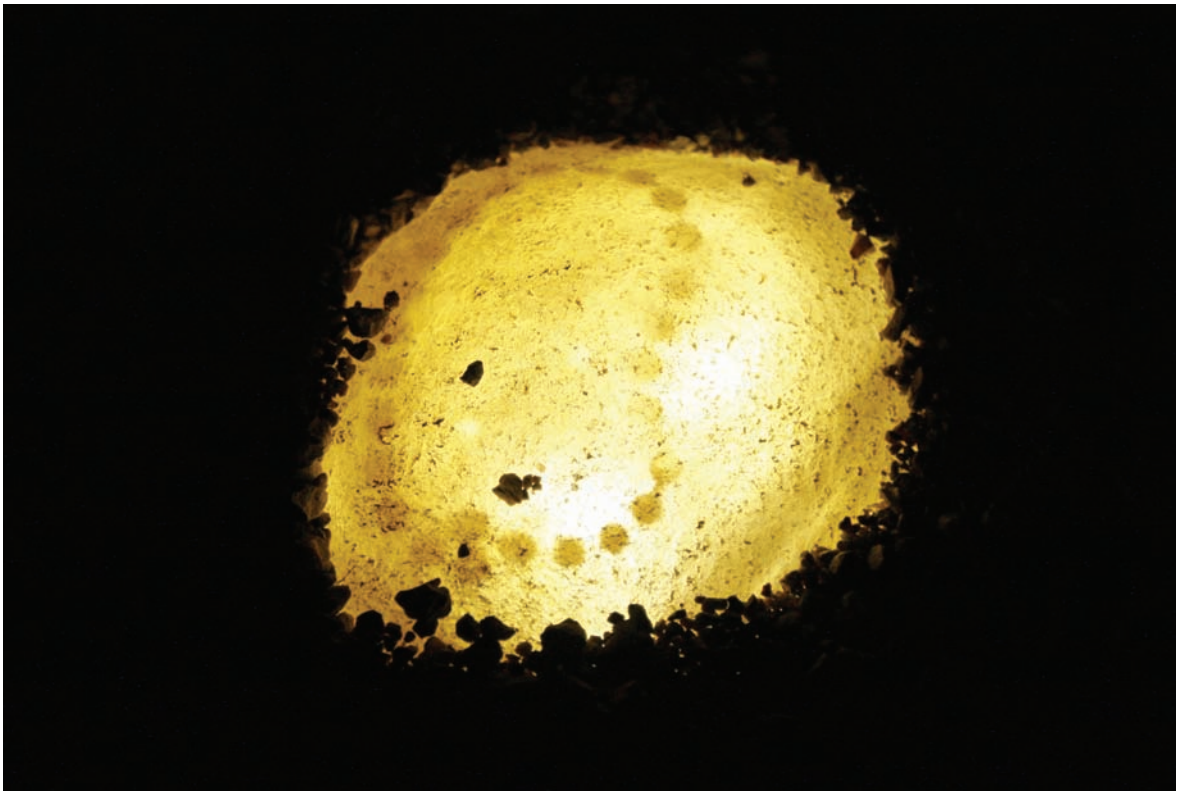
Energy Efficiency

Lighting designers have to take into consideration, among others, three basic principles concerning energy consumption of a lighting installation:

- Design of lighting installations with the less possible energy consumption.
- Use of the appropriate technology, light sources, dimming and control systems and right maintenance of the equipment.
- Review of lighting concept with regards to energy use and sustainability.

Light pollution

Bringing light to the places where it is required and when it is required is essential in reducing light pollution and unnecessary sky glow. Control over spill light, light trespassing and use of targeted light will ensure a reduction in sky glow and wastage of light and energy. Moreover, attention needs to be given to the spectral distribution of the light source so that it is not harmful to the nocturnal life. Light sources and lighting components should be completely free from any harmful chemicals, elements or reactants that can pollute the environment in any way.



LED Luminaire Cost Perspectives

LED LUMINAIRE ITSELF IS A COMPLEX SYSTEM INVOLVING SEVERAL ASPECTS THAT compose the luminaire and its system cost. There are two main ways for creation of luminairies, and thus impacting the prices – design of individual or small scale series of LED luminaires for the individual use of person in private territories or in public spaces for enhancing the visual effect of lightened space. These types of luminaires will always be in high prices range and the impact of the technology prices will not drastically reduce the production. This is resulted by the expensive design and small quantities of luminaires. Also customers in this case request a superb quality, which raise the price due to the expensive parts.

Thus the standardised production and design of LED luminaires makes the product prices reduce. The reductions of prices of LED luminaires are caused by such factors: standardisation of products – this part of price reduction factor has one of the biggest effects. The lack of standardized equipment means a lot of variety of products in the market and may result a low quality product enter to the market.

Though the low quality product has lower prices, but it has a side effect – the low quality product stops the future expansion of newer products of penetration in the market, resulting lower quantities in production and higher prices in the end. This reduces the inrush rate of new technology in the users preview not only due to the cautious usage of new product, but also the higher price. The standardization first of all describes minimum requirements for the product and thus sets the quality standards and would increase confidence in the user part, increase usage, but also will give guidance to the manufacturers, which reduces the part of design cost.

Patenting may play a huge role in prices. If the patent information is not shared – the manufacturers are forced to invest in scientific innovation and try to find solutions that will not violate the patented rights of other manufacturers. This leads to the increase of prices, though the technology would spread in the future more widely but due to the mentioned facts the prices might not reduce as quickly as expected from the market consumers.

Planned obsolescence has an impact to the prices and reliability. It reduces the reliability of product after guarantee period and thus impacts the usage increase. But the longer the guarantee, then the higher the price of the product due to the reduction of product sells.

Advertising – at this period when LED technology is emerging in market, the advertisement takes a big part at the beginning, when the consumer and users of the technology must be persuaded to purchase the product.

The reason of prices increase is that in a lot of municipalities the installed HPS lamps are still not fully made revenue of the installation and financing the new installations with LED luminaires for public lighting.

Market increase expands competition and makes the prices to decrease, because the expanded production reduces the costs of: design cost for unit; bigger quantity of material usage, gives for the manufacturers' better opportunities to negotiate for lower material prices with material providers; lower power consumption for productions; lower transportation costs per unit, and some other costs.

The prices of LED luminaires are also very dependable on the material and energy costs, which are mostly dependable on political and demand/offer ratio. The political issue mostly makes prices to rise, so the stability of the political arena in the world, especially in the energy production sector is a vital issue. The material sector is not so significantly dependable on political issues so it is possible to find new resources for the LED component materials in the world. The main material used in the production processes – aluminium, copper, iron, etc. and alloys for poles and casing, also for reflectors, wiring, heat sinks, soldering; semiconductor elements, plastics and glass also special casings, textolite.

The price of LED luminaires also is dependable upon the transportation costs, which not only means the transportation from the manufacturer to the reseller or to the customer, but also the transportation of the materials from the material provider to the manufacturer.

The personal costs – is the costs, which vary in different region of the world, especially China's working force is very cheep. This means that the production in the China is cheaper and results that most of the world manufactured LEDs are coming from that country.

The taxes – this is an issue of the governmental policy in each country, which produces the LED luminaires.

Maintenance costs – these costs tend to reduce the total final cost of luminaire, due to the – lower power consumption, the better colour rendering of LED produces a better recognition of the object and thus results the need of lower power LED luminaires to get the same visibility effect and results the electricity costs go lower more.

The brand – the well known brand is the source of the price increasing. So the reduction of price for the customer would be the search of the same quality products among the brands less known than the leading ones in the market.

The light control increases the installation costs and reduces the maintenance costs. The light control of LED luminaire is enabled by the control unit inside the luminaire itself, but the control signal could be created by several issues – sensing of illumination of the spot, controlled by the computer or by operator.

The structure of LED luminaire: LEDs; power supply source; casing; heat sink, reflectors; diffusers; pole; wiring; control system – wireless (Bluetooth, Wi-Fi, radio waves) or wired – by special serial ports, industrial connections (Profibus) or using supply power cable system; control program and its design; sensors of illumination temperature and humidity; fastening materials and equipment. These are parts depend upon the need of the luminaire characteristics, but there are several parts which are required in LED luminaires and are not so strictly used – the diffusers – this is needed of the reduction of the multi shadowing and glare effect. All the additional parts are increasing the prices of LED.

One of the reasons which might have a huge effect on the prices – is the new technology (other than white LED) entering the market and making the competition to the older technology, thus reducing the latter prices. The upcoming technologies are: OLED (now evolving), LET (light emitting transistors), OLET (organic light emitting transistors), using bioluminescence effect, light storage (the distant future technology), lasers (which are developed, but not well introduced to the lighting market) and other.

So the cost of luminaries depends on various aspects, not only on what type of luminaries characteristics have to be reached. The bettering of luminaries characteristics, such as CRI, CCT, lm/W rate, controllability, electrical efficiency, increase efficiency of reflectors and diffusers, quality of light beam distribution, increasing power factor, lowering the fault rate of luminaries components, lowering the shadow effects etc. increases the price of luminaries, but it helps to decrease the maintenance costs during the service period.

Thus, the costs are also dependable on the quantity of the produced luminaries. If the individuality of production will be not reduced, than the prices and costs of luminaries will be higher. If the huge series of the same luminaries will be presented to the market – this definitely will cause reduction of installations price.

Economy LED Versus Conventional Lighting

To compare the cost of LED lighting with conventional lighting should take account of:

Materials:

The difference in investment cost for the material between the LED and conventional lighting is in the price of the fixture. conventional lighting costs about 190€ while the same brand of LED cost between 300-1000€.

Installation Cost:

Installation costs for a light fixture in the facility is now virtually the same for LED and conventional luminaires.

Operating costs are different from the LED and conventional lighting on the following points:

- Energy: LED lights are more energy efficient compared to conventional lighting
- Relamping: Conventional lighting need change of light source after 16 000h at a cost of about 17€

Troubleshooting and supervision currently costs about 2€ per year but is assumed to be 0€ for LED lighting.

Cost estimate:

The following formula can be used to compare the cost of conventional lighting in LED luminaire lifetime: Purchase price + power of the system *Operating time* energy price + monitoring / trouble-shooting + lamp replacement every 4 years.

If you look at the suppliers we use today such as Philips Siteco Thorn will see the pricing looks as follows.

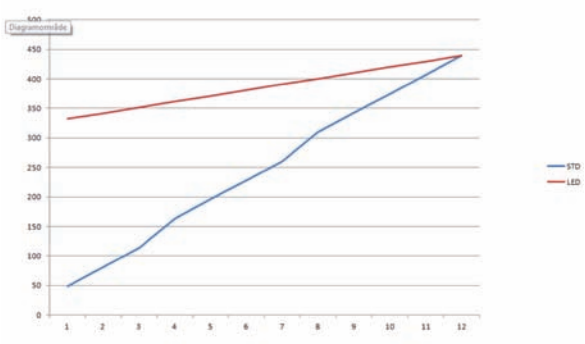
CDO/Nah fixture	193 €
LED fixture	400-1 000 €
Replacement of fixture (mount)	50 €
Troubleshooting /supervision	2,2 €
Relamping (every 4 years)	16,60 €
Energy price:	0,12 €
Operating time	4070h

Reinvestment / maintain existing fixtures:

What will the maximum cost of a LED luminaire be if the reinvestment should break even during the LED luminaire life time 50 000h. Number in red indicates maximum price for the LED luminaire if the price continues to go out:

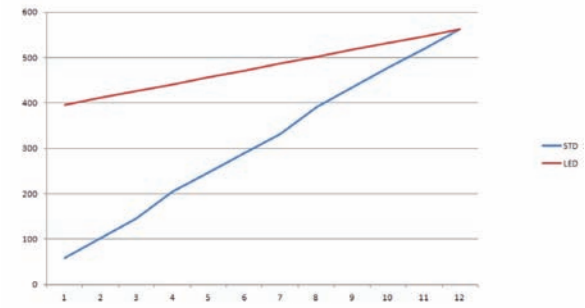
Example 50 W Nah -> 20 W LED

Purchase price CDO Nah (EURO)	16.60
Purchase price LED (EURO)	272
Effect LED (W)	20
Effect standard (W)	62
Lamp replacement (EURO)	16.60
Supervision (EURO)	2.20
Energy price (EURO)	0.12
Operating time per year (hrs)	4 070
Replacement of fixture (??)	50



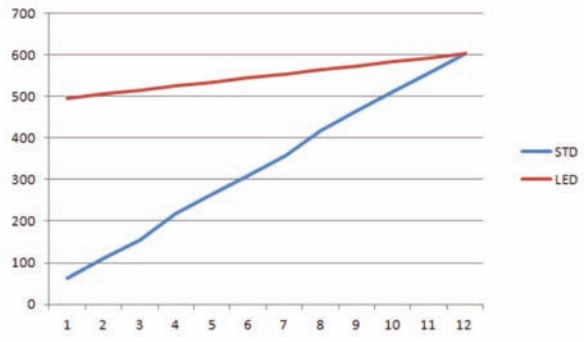
Example 70 W Nah -> 31 W LED

Purchase price CDO Nah (EURO)	16.60
Purchase price LED (EURO)	331
Effect LED (W)	31
Effect standard (W)	83
Lamp replacement (EURO)	16.60
Supervision (EURO)	2.20
Energy price (EURO)	0.12
Operating time per year (hrs)	4 070
Replacement of fixture (??)	50



Example 80 W Hg -> 20 W LED

Purchase price CDO Nah (EURO)	16.60
Purchase price LED (EURO)	436
Effect LED (W)	20
Effect standard (W)	90
Lamp replacement (EURO)	16.60
Supervision (EURO)	2.20
Energy price (EURO)	0.12
Operating time per year (hrs)	4 070
Replacement of fixture (??)	50

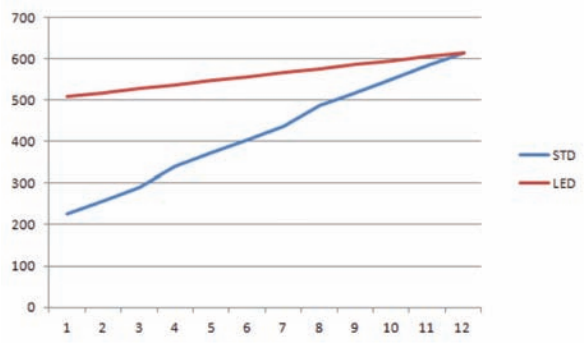


Investment new lighting installation:

What will the maximum cost of a LED luminaire be if the investment and costs during the LED luminaire life time 50 000h should be equal or less compared to conventional lighting. Number in red indicates maximum price for the LED luminaire:

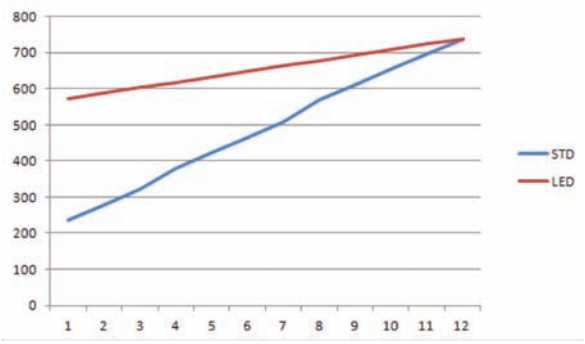
Example 50 W Nah -> 20 W LED

Purchase price CDO Nah (EURO)	193
Purchase price LED (EURO)	499
Effect LED (W)	20
Effect standard (W)	62
Lamp replacement (EURO)	16.60
Supervision (EURO)	2.20
Energy price (EURO)	0.12
Operating time per year (hrs)	4 070
Replacement of fixture (??)	0



Example 70 W Nah -> 31 W LED

Purchase price CDO Nah (EURO)	193
Purchase price LED (EURO)	557
Effect LED (W)	31
Effect standard (W)	83
Lamp replacement (EURO)	16.60
Supervision (EURO)	2.20
Energy price (EURO)	0.12
Operating time per year (hrs)	4 070
Replacement of fixture (??)	0



Conclusion

The initial investment of lighting installations, it is already economically justified to choose LED lighting over conventional lighting in a facility with standard equipment. Provided, however, that the price of the selected fixture is on max 560 €.

A decision on reinvestment in existing lighting system (not Hg) requires that prices are going down to 300 € in order to be economically justified to choose LED lighting over conventional lighting. A prerequisite for this is that the existing plant has a life expectancy of at least 12 years.

Reinvestment of Hg plant can now be counted as a new investment when mercury lamps are being phased out.

The investment must not be short term, but must take into account the luminaires entire life.

If the investor is not the same person who will manage the operation, it may be a problem, in these cases is often selected conventional lighting because of a lower purchase price for the fixture.

Light on the Political Agenda

WHENEVER A MAJOR TECHNOLOGICAL SHIFT AFFECTS THE GENERAL PUBLIC, politicians are called upon. The reason is that they represent a major market force and a substantial part of the economy in any part of the world. Politicians control most of the roads, walk- and bicycle-ways, bridges, parks and other urban spaces. Politicians also control a huge infrastructure with offices, schools, hospitals, libraries and other public buildings. Both outdoor and indoor they possess power over a huge part of the public spending on electricity for various purposes. Public light is one major expense for many cities and municipalities.

LED, a solid state technology that wavers promises about public light with low energy consumtion, a long lifetime, a minimum maintenance and good color rendering. It is all to good to be true, but manufacturers that makes the claims have our attention. Now it is a question of confidence and our own learning curve as procurement organizations.

No publicly elected person spend huge amount of taxpayer's money on something they are not sure about. They need confidence in the technology, in the products, in test results and in emerging or established standards. Everything needs to be validated. And all claims about long-term economic gain have to be convincing. Then , and only then, they can consider putting the pressure on the market to deliver what has been promised. And they will, if the claims tend to be true!

Projects where cities and municipalities come together and perform real life testing of is a vital part of the pre-processing for a new technology like LED light. Politicians are among peers and trust each other since they have the same objectives. It is to enhance our cities for the benefit of our citizens and our visitors and use resources in an economical way at the same time.

But without a big market there is no mass production. Whithout mass production there is no lowering in prices. Without many producers there is no competition. Without competition there is no development.

Someone has to go one step ahead and start the process. The public sector must take that responsibility and kick-start the process. China started some years ago, but had to back down. They spent billions on locally produced LED light fittings for their brand new infrastructure. They have stopped and realized that they went to fast and that they need standards, specifications to test against and knowledge about characteristics the new light source.

On the other hand we learn form many cities around the world about huge success for the new LED technology. The market is maturing and growing worldwide. So the field is open and we have to benefit from each other's experience, successes and failures. Now we need accelerate and put pressure on EU to produce common standards, we need to sharpen our procurement skills and we need to cooperate with the emerging industry to start implementing.

But we also need to further and develop the local distribution and service structure. We need to explore then new possibilities that LED SSL offers like monitoring, wireless control systems and intelligent light management.

It is all about public benefit and the use of technology to enhance our lives.

Conclusion

ARTIFICIAL LIGHT HAS TO OFFER A GREAT QUALITY OF LIGHT DURING DARK HOURS fulfilling as much as it is possible the needs of the user in each case. Lighting is a tool that can help planners and designers to enhance the structure of the city, pointing out the different activities in different public spaces, creating an environment that fits to user's needs. White LED light is an appealing solution for urban environments but the continuous progress and update of LED technology make the municipalities still think of it and delay the installation of new equipment. Moreover, it is a sustainable solution and also reduces the impact of human on the environment.

The analysis of the existing standards, the new technology and the possibilities that the last offers lead to a point that the need for reviewing standards and expanded approaches is imperative. There was proposal of approaches and recommendations that could be followed in order to create both quantitative and qualitative standards and regulations.

There are rules for the amount of light that is appropriate with technical approach but there is not recommendation for the architectural part of the installation. It is really important to establish not only quantitative but also qualitative standards for LED technology based on good lighting conditions for the user.

Proposals of new fields and recommendations for new standards must be done focusing on user's needs, having a humanistic approach, and not only led as product. New techniques, according to which new understandings could be created, must be established.

The location, the kind of use, the group of users, they all stand for certain necessities or user demands which needs to be regarding during the planning of a lighting installation. For each project the composition of the set of demands and restrictions are unique and have to be addressed for the specific situation. LED technology supports a great variety of fixtures and lighting equipment that can fulfil different concepts.

Finally, the right communication of the ideas among the involved partners during the whole process and planning of the project is significantly important. Guides and planning tools would help all municipalities and authorities to develop Lighting Master plans for urban areas in collaboration with professional lighting designers and engineers involving also the general public in the whole design process.


Oskarshamn
Kalmar
Bad Doberan
Wismar
Rostock
Gdansk

Part three
The Project Installations

The Project's LED Light Installations

THIS CHAPTER DEALS WITH THE PILOT INSTALLATIONS THAT DESIGNED AND delivered through the three years that the project was running. It is part of the project where there is interaction between planners, municipalities and manufactures. Apart from the presentation of the installations, there is also an attempt to note the practical and communicative difficulties during this process.

A lot of times, municipalities have discussion if it needs to wait sometime before replacing an old installation by LEDs or installing a new one, due to the adjacent development of LED technology. From one side, this is true because the light output is continuously improved but there are also other points of investigation and progress which are not directly affected by the light output and could be used in a design that could last longer:

- How can LED be integrated in an urban environment?
- Controlling and monitoring of LEDs.
- Design of fixtures.
- LED light distribution.
- Standards for mounting LED, etc.

So, if manufacturers and designers work with every aspect/point of LED lighting and not only on the light output, the lm/W value would be a bonus over the years. For example, there is the possibility that a LED fixture can give 50% of the needed light if it is just replaced an old light source on an existing pole, but 150% of the needed light if the pole is redesigned and have for example a lower height.

The luminaire integrated with a control system should be able to:

- Logs of running time.
- Check the functionality and accuracy of all the components of the installation.
- Control the light output.
- Control the colour temperature.
- Regulate the value of CRI.
- Detect movements.
- Include a built-in systems such as radio communication.

The installations in the LED project is aimed to mirror possibilities with LED at a pedestrian perspective. We have in this project learned how difficult it can be to do the best possible installation using LED, one of the main difficulties is the never-ending possibilities we have learned over time.

We had the thinking that energy efficiently equals the amount of light that reaches a certain defined surface. Doing light calculations this way makes it easy to compare different light sources. This is the way it has been done in the past and also the way many in the business are used to. We have reached the knowledge in the LED project that calculations shouldn't be done so easy as it has been done.

Since the LED technique has more options to offer than older technology we have to in the future ask suppliers differently in order to get the best lighting situation. It is now possible to not ask a surface what light he needs, we can ask the pedestrian.

Again one big barrier to climb is what questions to ask and how to convince suppliers, installers and purchasers that a different method to design a place with light should be used. We have meet many suppliers, manufactures etc during the project time and very few take the risk to really use the largest benefits with LED, they often continue to use old methods like amount of light at a surface and life cost analyses. Since almost every purchaser lack the skills on how to define a god light installations they depend on the suppliers that are stuck in an old technology. We hope that in a near future, purchasers, municipalities, architects start to ask questions about light and the pedestrian in the light instead of asking questions about products and life time of the products.

It is really annoying that it is technically possible to have a light source with LED with a high CRI, possible to control, variable Kelvin value, possible to design as one piece but it's not on the market!

The installations done in this project we believe will speed up the process using LED in the future. In Bad Doberan we have showed the many possibilities with LED in a school and this could be something for other schools to learn from. In Oskarshamn we have done installations without any connection to the grid which is both possible and suitable for the LED. Gdansk are showing how just a little bit of light can reach the interest from people and forget about the darkness.

Kalmars installations has the aim to show LED with high CRI and interactivity with the pedestrian, easy to accomplish with LED, we just have to do it.

We hope you will read more about the installations in the following pages and also visit one or more of them. But most of all, we hope that you, having read this chapter, will think more about the light in combination with the space and pedestrian instead of the product.

During the project, planners and municipalities have met with suppliers of LED luminaires and components and tried to assess these products. Many vendors have lent fixtures to be tested.

In the planning and designing process of the installations in Germany, University of Applied Sciences Wismar has worked as consultant providing advice and ideas.

The following are some of the fixtures that the partners in Kalmar looked at. We found that the industry in many ways shows the same products.

Sundlight

Sundlight Neighborhood

Adulux

Fagerhult Stela


Lumi R10



Installation in Gdansk, Poland

The installation in Gdansk use LED in a very interesting way. By adding a little bit of light, pedestrians regard the surrounding as a more comfortable area. Since it is easy to control LED-light this installation consists of a number of molded "Amber drops". Inside the Amber drops, a controlable LED is applied.

By controlling the light the installation brings interest to the pedestrian, focusing at the light. The spot has developed from an quite unpleasant area to a place where you want to spend time.

Process

The Centre for Contemporary Art *Laznia* is an urban unit responsible for carrying out a programme called *The Outdoor Gallery of the City of Gdansk*. The art installation *Amber Drops* is part of this programme.

The tender procedure was initiated at the beginning of 2011. Two bids were submitted. In accordance with Polish law on public procurement the company that offered the lowest price was chosen. The contract with ELMarco was signed July 11, 2011.

The tendering procedure lasted longer than originally expected, because the prices of both bids were higher than estimated in the terms of reference. Therefore the funds for the Amber Drops installation needed to be increased, which required a decision of the City Council.

The necessary ground work prior to the assembly of the Amber Drops installation started shortly after signing the contract. Then the LED lighting assembly was carried out. Finally, the installation was put into service on 28 October 2011.

Regional aspect

The Amber Drops installation is located in a district called Lower Town, very close to the historic city centre of Gdansk. It is part of the the Outdoor Gallery of the City of Gdansk – an urban culture programme managed by the Centre for Contemporary Art Laznia. Thos programme aims at improving the quality of public space through implementation of various projects.

All activities, developed through the years, will contribute to the social and architectural transformation of one of the most deprived areas of Gdansk and initiate changes to the character of the district. Within this project a collection of works of art will be built as a permanent element of the landscape, thus increasing attractiveness of urban space and helping to create a welcoming places for permanent inhabitants as well as tourists.

The Amber Drops project was designed by Fred Hatt and Daniel Schlaepfer, two Swiss artists who have been awarded the third edition of the Outdoor Gallery international competition for its reference to the importance of amber in the identity of Gdansk.

The installation, located in the space under the bridge above Szopy Street, is formed with yellow translucent pebbles made of epoxy resin. In total there are 49 amber drops with a built in LED lighting system, divided into groups.

They are all sufficiently hard to support the weight of people standing on them. Objects of different size and type are hidden in the lighting fitting; some household articles, such as a comb, scissors, glassesare embedded into the resin.

The Amber Drops are connected to an electronic control system, alllowing them to function independently in accordance to sequences and screenplays. While walking down to Laznia one could take a break and sit down on one of the five benches to have a quiet moment in the busy daily life.

The Amber Drops Installation.

At night the space with the pulsating glow area and the sound of gravel crunching under your feet as you walk, creates a unique atmosphere, cutting you away from everyday life's worries and giving you a moment of rest each time you visit Amber Drops.

Installation in Bad Doberan-Biendorf, Germany

The installation in Biendorf demonstrate the variety of LED in a school. A lot of installation is made and are well received by the users.

Process

At the beginning of the project period, a demonstration of a luminaire from Philips was carried out in order to make the difference between the very yellowish light from conventional sodium high pressure luminaires with poor colour rendering, to a warm white light obvious to the decision-makers of the municipality. This demonstration convinced the authorities that a change was necessary.

The installation alsom made it possible to save energy, as 70 W conventional luminaire was replaced by 30 W LED. Because of financial strains the municipality turn off all street lighting between 10 PM to 6 AM. Also only every second luminaire is turned on.

Situation after installation

Improvement of the security and comfort for users, encouraging more intense use of location, inspiring new users groups, playful use of light for kindergarten, grid independent lighting, energy saving. The building should be visible from the street as an important building for the village without being prominently lit.

As a whole the target was reached quite excessively. It ended up with a sophisticated diversity of LED installations. If it had been possible to convert all conventional luminaires around the community centre the result would have been even more obvious and useful, but the activities had to be concentrated on a very small area. The only exceptions are the solar fed installations in four villages of the municipality, i.e. Wischuer, Westenbrügge, Körchow and Berghausen.

However, the mayor pointed out during the visit of the project delegation in Biendorf March 27, 2012 that he intends to convert every street lamp in the municipality into LED technology within the next few years. He especially referred to the energy saving aspect of LED.

Test area kindergarten and community centre

Façade lighting - 4 x Sill spots, 18 W, 3.000 K, dimmable.

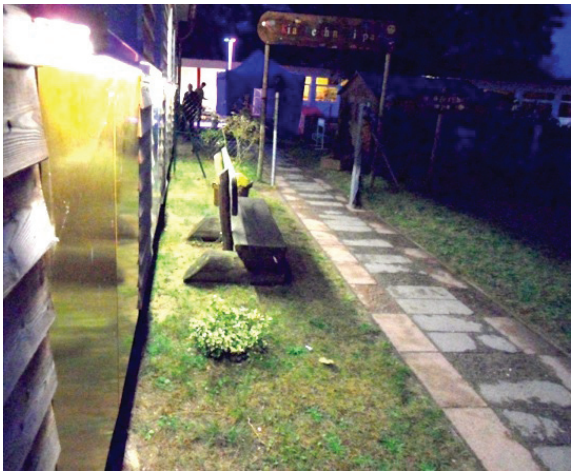
From the beginning of the preparation of the application until the realisation of the installations the cooperation with the municipality was very fruitful.

The planning process took place as follows:

- Rough planning with representatives of the Municipality.
- Assignment of an electrical engineer for detailed planning and tender process
- Locations for new installations and for converting conventional luminiaires

- Market research – preselection of manufacturers/installations
- User's needs – 1st questionnaire before installation
- Realisation of installations
- Opening event – information/recommandations for decision makers and inhabitants.

The process during the research period and tendering was realised with no greater obstacles. Before the tendering was initiated there was a long phase of considering needs and options for the new lighting situation in the test area. The bad lighting situation around the community centre was chosen for very varied installations.



LED-lines for path lighting, RZB, 4 x 9 W, 3.300° K.

Flexible LED-lines for backlighting the name boards of the kindergarten, Osram, 80 W, 3.300° K.

Sill LED spots for lighting up parking ground and entrance 8 x 30 W, 3.300° K, dimmable.

Children's game with colour mixing – Sill RGB-spots with light control for colour mixing, 3 x 80 W.

In the small villages where the self-sufficient solar lid installations were realised the lighting situation was very poor if not non-existing.

One of the considerations was that the community centre should be more visible from the street as an important building for the village without being too prominently lit. To reach this target a faced lighting was chosen which lights up the building at times when it is usually used: the early evening.

As it was a community centre with an attached kindergarten, it was preferable to install interesting light seen from a child's view - the idea with the children's game arose. After a long period with consultations with manufactures about the possibilities of new development of such a game an exiting type was chosen because the budget set certain limits. The experience with most manufactures was that they had never thought about developing a product like this, but they found this enquiry very interesting and innovative.

The intention with the information board was to combine the practical aspect of information of the inhabitants about ongoing activities in their community with information about LED project and LED-technology in general.

At the same time, intention was to show the great possibilities of mixing light colour and also the different white LED light, because one of the prejudices towards LED light is, that it is a bluish, cold light. Three different variants with respectively 3000°, 5000° and 6500° Kelvin was chosen.

Another very important spot that should be illuminated was the parking space in front of the centre and the path from there to the entrances. An electrical engineer was assigned to plan the installations in co-operation with the University of Wismar. During this work the choice of products was made.

The electricians called for tenders from the manufacturers of the specific products. The time of delivery was kept so that the acceptance of the construction work could take place as planned.

The co-operation with the Municipality was of great value, all ground work was made by municipality workers. Almost all favoured installations were realised. Though one planned solar fed luminaire had to be left out, because the full potential of the budget for installations was tapped.

Representatives of the municipality appreciate very much that no vandalism has been noticed. They were very afraid that this could happen, because it is not unusual in the area. They presume that the inhabitants feel well informed and involved in the process and appreciate the innovations.

3 x Solar-LED combination, grid independent information boards fed by solar panels, RZB/Leuchten GmbH Pasewalk.

Solar-LED luminaire in Berghausen as self sufficient installation – Leuchten GmbH, Pasewalk, 28 W, 3.400° K.

Problems

The solar panel on one site caused some problems. Several enquiries from the municipality had received and citizens wondering why the light was out or only flashing. Meanwhile the supplier replaced a defective component and was very keen on solving the problem as fast as possible. Yet the very cold weather in the late winter delayed the plan for a few weeks.

The manufactures and the electricians were very co-operative during the whole process. All other solar panels have turned out to be reliable, even in the fall and winter (this was the first test period, since the installations were completed by the end of September).

There were many attempts to persuade the mayor to at least leave all LED installations turned on during the night without any result. We hope to change the attitude, in consideration of the fact that he plans to convert all street lighting within the next few years. The improvement of the lighting situation as a whole should also be facile.

There was the intention of a dimming solution allowing a more sophisticated controlling. This would, however, cause cost exceeding the budget. A hand dimmed solution was chosen instead.

Regional aspect

Attitude of inhabitants in rural areas towards lighting

Representing a rural area, it was noticed that people in the pilot area of Bad Doberan-Biendorf have a different view of the lighting situation than citizens of a larger town seem to have.

In the first questionnaire, before the installation was realised, many of the answers actually stated that the lighting situation in relation to the traffic situation in Biendorf was considered good or at least satisfying.

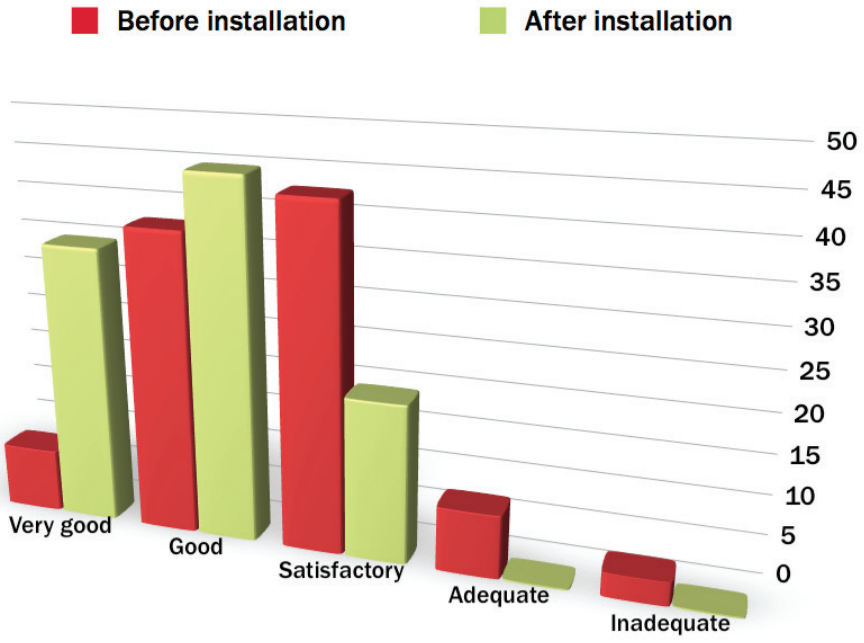
The number of yes and no answers of the question whether they would feel safer with more light on the streets was almost the same.

Before the project was initiated all street lighting in the test area was lid by sodium lamps with a very yellowish colour with disadvantages in colour rendering et cetera.

Despite of this, more than 85 % said they found the public lighting in their surroundings pleasant. Presumably tradition and habit play a great role here. Many people associate living on the country side with tranquillity, simplicity and without a lot of "light pollution". It is often heard: "I don't see that we need any kind of light at all". This is probably also why the inhabitants accept the fact that only every second street lamp is turned on.

The second questionnaire after the installations had been realised showed that 95% of the inhabitants indeed had noticed the new lighting situation in their villages.

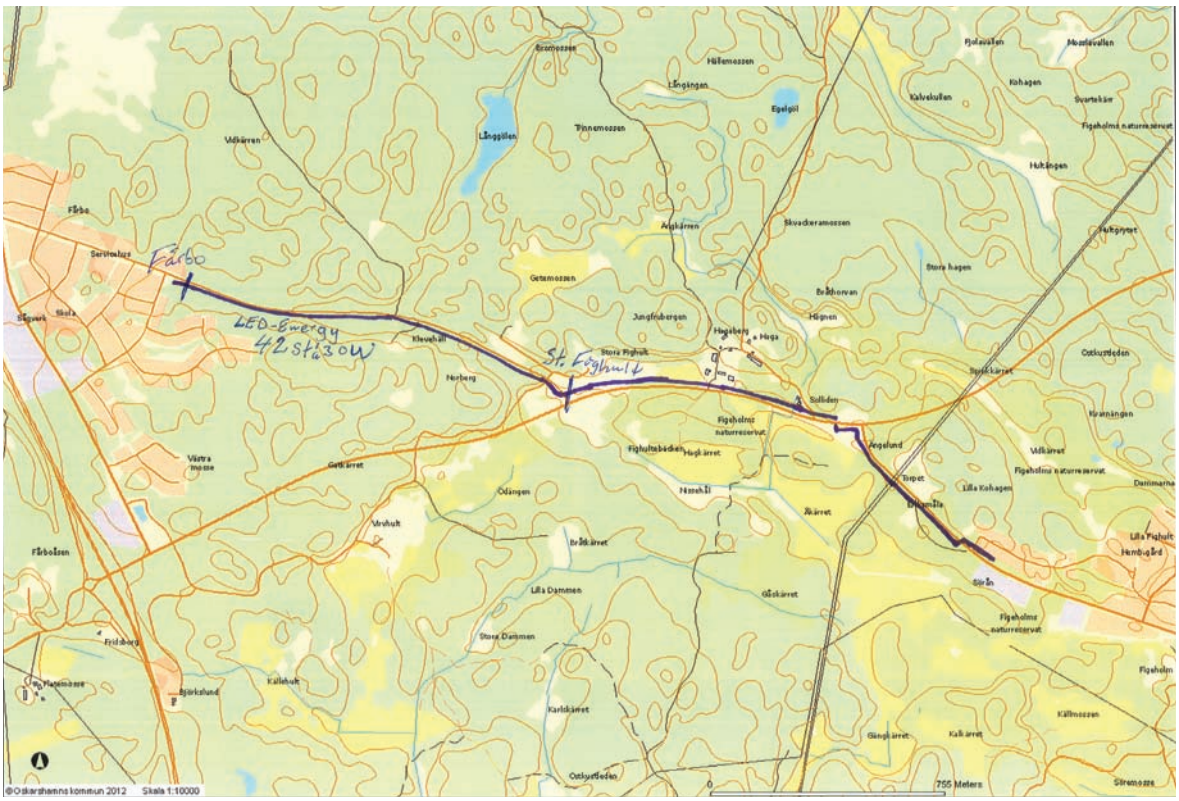
More than 61% said that they now feel more safe in Biendorf. Presumably the no-answers originate from users that don't use the community center/ kindergarten daily.



The diagram above show the perception of the new lighting situation in comparison to the former situation. The question was *How do you judge the public lighting situation in Biendorf?*

Installation in Oskarshamn, Sweden

In Oskarshamn one big challenge was to build a LED installation off-grid. Two attempts were made and the second was installed. A bicycle street LED installation was also made.



Pedestrian and cycling roadway Fårbo-Figeholm

Length: 1 600 meters construction (Fighult- Figeholm). 1 250 meters lighting bef GC path (Fårbo-Fighult). Width 3 meters

Calculated pole distance: about 30 meters

Estimated pole height: 5.5 meters

Luminaire bracket of standard model, diameter 65 mm

Coloration of light: at least 3500 kelvin

Conceived illuminance: 30 W

Luminaires (plant) equipped for adjustable illumination, e.g. 16:00-23:00 hrs 100 %, 23:00-06:00 hrs 30 %, 06:00-08:00 hrs 100%

Contractor/supplier is responsible for wiring and commissioning of luminaires. Technical office stands for cable trench, setting of pole foundations and poles. The project had a lighting system set up. It includes 92 pcs lighting points (LED:s) each 35 W.

	W/h	Function hours		Total W
Traditional lighting 92 fixtures 80 W	7 360	16:00-08:00	16 h	117 760
92 LED Fixtures				
35 W	3 220	16:00-23:00	7 h	22 540
17 W	1 564	23:00-05:00	6 h	9 384
35 W	3 220	05:00-08:00	3 h	9 660
			Savings	**76 176**

What does this mean in money?

- Energy price 2010: 0,77 SEK/kWh excl VAT, (appr. 0,09 €).
- Daily saving is 76,176 kWh.
- Daily saving is 6,86 €.
- Monthly saving is 2361,456kWh.
- Monthly saving is 204,87 €.

Besides that the road has become much safer and people are out more. Children ride their bikes between Fårbo and Figeholm to be able to play bandy and football. This was out of the question before.

Within the project, it was chosen to focus on the following factors:

- Low voltage system 12 V or 24 V.
  By driving lights with only low voltage, the required earthwork for the installation of cabling was easier. This lowers installation costs significantly.

- Wind or solar energy
  It was chosen wind generator or solar panel in order the light be independent of the power supply. These generators provide 75 to 130 W.
- Storage of electricity via battery
  It was chosen type battery Lead-acid (Lead) 12V, 85 Ah, to store the electricity. The voltage (12-13 V) is regulated via a regulator.
- Real need of light
  The lighting is controlled by a motion detector and lit only at night when someone passes. This method saves significant operating costs in long term.

Self-sufficient lamp posts

One at the entrance of the Technical Department and one at Brädholmen.

- 12 V battery.
- 200 W wind turbine.
- Sensor.
- Steering system

Process

The walk path and bicycle lane between Fårbo and Figeholm is a relatively trafficked road between two communities in the municipality, which was without any lighting. There was a clear need for the pedestrian users. Information within the LED-project proved to be very valuable before installing the 92 lighting points. In the installation the pedestrian was clearly in focus with aimed lighting to their part of the road.

Information, know-how and networks from the LED-project have been very useful and good contacts have been made between partners, with manufacturers etc.

Taking part in the installation did the projection engineer, the project leader of the Technical department for the LED-project and the investigational engineer with responsibility for street lighting.

Regional aspect

Within the project the team in Oskarshamn wanted to find an energy solution for lighting paths and cycleways experienced dark and insecure.

They wanted to test the LED streetlights products as an alternative to the traditional lighting, to reduce energy consumption in Oskarshamn Municipality and to provide better security.

There has been an issue of safety and security, an obvious need to get the walk path and bicycle lane lit up. Parents were afraid to let their children walk or ride their bike their due to the traffic. It was an important issue for politicians, civil servants and the public.

Installation in Rostock, Germany

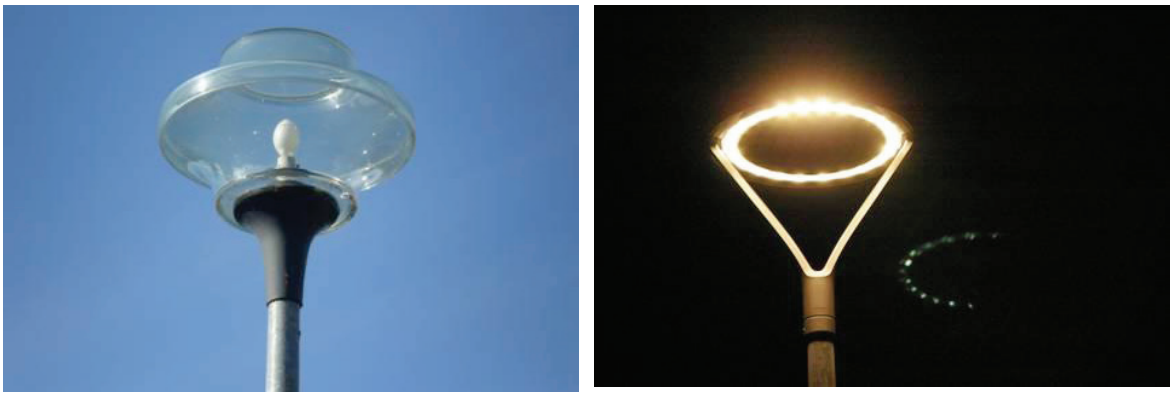
The LED-project Schwanenteich consists of two parts. The first was a pragmatic activity with the aim to substitute an inefficient lighting installation based on mercury lamps. The second was to create an esthetical illumination the city's art hall facade. The aim was here to create a more attractive art hall including the surrounding field.

Independent of the actual substitution of luminaires the City of Rostock created a cultural heritage preservation for the hole of the Schwanenteich park area. The result was to abandon lighting in some park paths. This number of light points was reduced from 52 to 37 pieces.

To find out the best suitable luminaire for the project, six different luminaires from five companies, Trilux, Selux, Philips, Leipziger Leuchten and Siteco was ordered

The illumination of the walls has been realised by a total of ten floodlights mounted on two 6m poles. One of the flood-light poles illuminates the southwest and the southeast wall. The other carries the floodlights for the north-west and the north-east wall. The other eight main floodlights (each 70W) have two alternative light distribution curves and realise a very good uniformity of the illuminance on the walls.

The luminaires contain RGB-LEDs, so that the walls could be irradiated with different light colours relevant to the different kinds of exhibitions inside the Art hall.



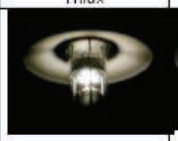
Old mercury lamp (left) 89W – 52 pieces. New LED lamp (right) 29W – 37 pieces.

Part I – Substitution of the street lighting of the park paths

Rostock's team removed from their primal vision of luminaires with the classical lantern shape, because this shape does not show the new possibilities of the LED luminaires. The choice was a luminaire DL 20 from the company Siteco, with a very slim body consisting of a coil that holds and cools the leds and a fork/bracket that holds the coil. The DL20 has got a designer prize and has an excellent performance, a particular small blinding rate that is difficult to realise with LED luminaires.

The luminaires were ordered in two different colour temperatures to test the characteristics of different light situations as well as the physiological influence to the observer. Along the park paths they were installed luminous sources with 3000 K colour temperature (warm white) and at the crossings luminous sources with 4000 K colour temperature (neutral white) and symmetrical light distribution.

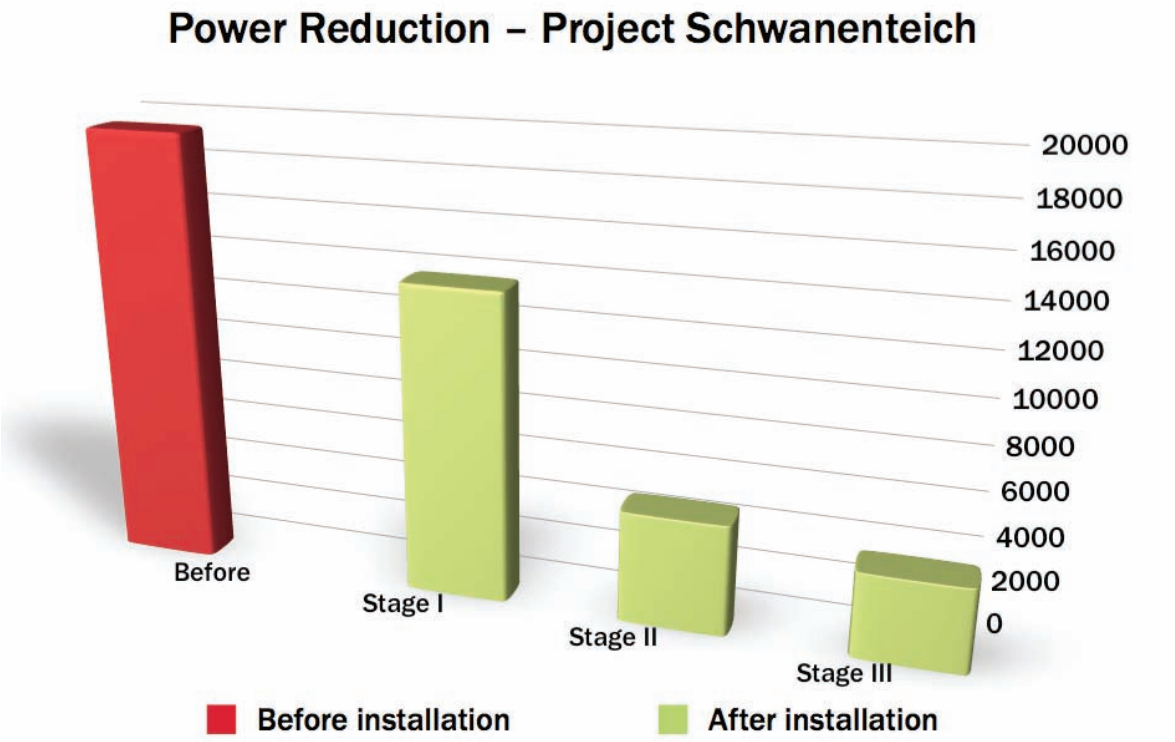
LED-Projekt Pilotanlage Wegebeleuchtung im Park am Schwanenteich

Nr.	1	2	3	4	5	6
Leuchte	9811 IS/LED	Saturn MTR 135 LED	City Spirit BDS 460	LEO II LED	City-Light	DL 20
Hersteller	Trilux	Selux	Philipps	Leipz. Leuchten	Siteco	Siteco
						
						
Anschlussleistung System (W)	32	36	25(30)	37	38 (38)	12 bis 29 (39)
Steuerungs-möglichkeiten						3 verschiedene Ausbaustufen mögl.
äußere Gestaltung	herkömmliche Leuchte ringförmige Blende bei LED-Einsatz nicht sinnvoll	herkömmliche Leuchte äußere Streben verschatten	herkömmliche Leuchte	herkömmliche Leuchte	herkömmliche Leuchte äußere Streben verschatten stark	innovativ, speziell für LED-Nutzung
Lichtwirkung (Messwerte in 5 m und 10 m Abstand)	+++	+	+++	++	+	+++
Lichtverteilung	asymmetrisch oder symmetrisch, indirekt strahlend	asymmetrisch oder symmetrisch, direkt strahlend	asymmetrisch oder symmetrisch, indirekt strahlend	asymmetrisch oder symmetrisch, indirekt strahlend	asymmetrisch direkt strahlend	symmetrisch direkt strahlend
Lichtfarbe (K)	Neutralweiß 4000	Neutralweiß 4000	Warmweiß 3000	Warmweiß 3000	Warmweiß 3000	Warmweiß 3000
Leuchtmittel-wechsel	Modultausch	Modultausch	Modultausch	nicht vorgesehen	Modultausch	nicht vorgesehen bzw. Modultausch

Power balance of the lighting installation – before and after led installation

The energy consumption has been reduced by the project in three stages. Energy consumption of the old installation was 19 440 kWh. In the first stage, after reducing the number of light points, energy consumption was reduced to 13 830 kWh. In the second stage, after substitution, energy consumption was lowered to 4 970 kWh. Finally, in the third stage, after substitution and dimming, energy consumtion was reduced to 3 770 kWh.

This means that after three reducing stages, the energy consumption in the new situation decreased to 19.4 %.



Part II- Illumination of the Art Hall by LED-floodlights

The illumination of the art hall is the esthetical and artistic part of Rostock's installations for the LED-project. The team was assured that the illumination of the outer walls of the art hall by LED-floodlights would make the building and the park surrounding the building, more attractive for tourists and residents.

Regional aspect

The first regular LED-outdoor lighting will be installed in 2013 in an area near the west bank of the river Warnow to light a pedestrian path between the bridges Petribrücke and Vorpommer-brücke. One reason to choose LED-luminaires besides low energy consumption and low carbon dioxide emission is the small attraction of LED-light for insects, especially close to the river bank.

Another regular project of outdoor lighting in public space will be a bigger one in a residential area in a quarter in the north west of Rostock. For preparing this project, a test phase will start in September 2012, evaluating in each case three luminaires from 5-6 different companies. After comparing the different types for 6-8 weeks, the best type of luminaires will be installed as regular street lighting in an area with six small parallel streets.

In the near future (2013 to 2014), it could be possible to continue the project to build up LED-installations for complete quarters.


OUT OF
CONTROL!
Arnulf Rainer

Installation Wismar, Germany

This installation shows the possibility to light an area with one high pole and to combine the same pole with LED fixtures for two different purposes.

Process

The test area for the project is a new built elementary school in Wismar. The part of the city is called Kagenmarkt and mostly consists of big apartment buildings. According to the development plan some reconstruction activities were on the agenda.

The old school building had to be replaced because of bad condition, other user`s demands and higher requirements towards safety, energy efficiency and space. Due to the situation the City of Wismar took the chance to build a new elementary school and combine it with the new technology of LED lights. The test area should be the building with school yard, parking lot, ways, bicycle stands and a green classroom.

The picture on the previous pagen (bottom) shows the new facilities: the school building and yard, the adventure playground, the green class room and the parking lot.

The situation before starting the project was bad or no light at all, inefficient technology and equipment, not suitable for the users: children, teachers and parents.

No lights were installed at the facades of the building to illuminate the main entrance and school yard, the bicycle stands and benches (left picture). The only lighting source for the entrance and the stairs was the inside lighting.

The same situation at the stairways and front (right picture): no lights at the facades of the front of the building and of the entrance of the three stairways A-B-C. The front and entrance to the stairways were only illuminated by public street lighting 15 to 50 metres away. The footway in front of the building and the entrance of stairways had no lighting! In winter the school yard was completely dark.

Together with the Wismar University several computer simulations of possible illumination have been set up to test different situations depending on weather, daytime or season.

After the above studies and simulations the kind of luminaries and LED modules as well as the location of the lights have been defined in order to prepare the procurement documents.

Regional aspect

The general aim of the project was to combine energy saving effects of lighting with the energy saving effects of new building materials (windows, facade, roof) and to test the different illumination effects (colours, brightness). The test area should also set a highlight of technology and creative work in a problematic living area to make it more attractive.

Installation in Kalmar, Sweden

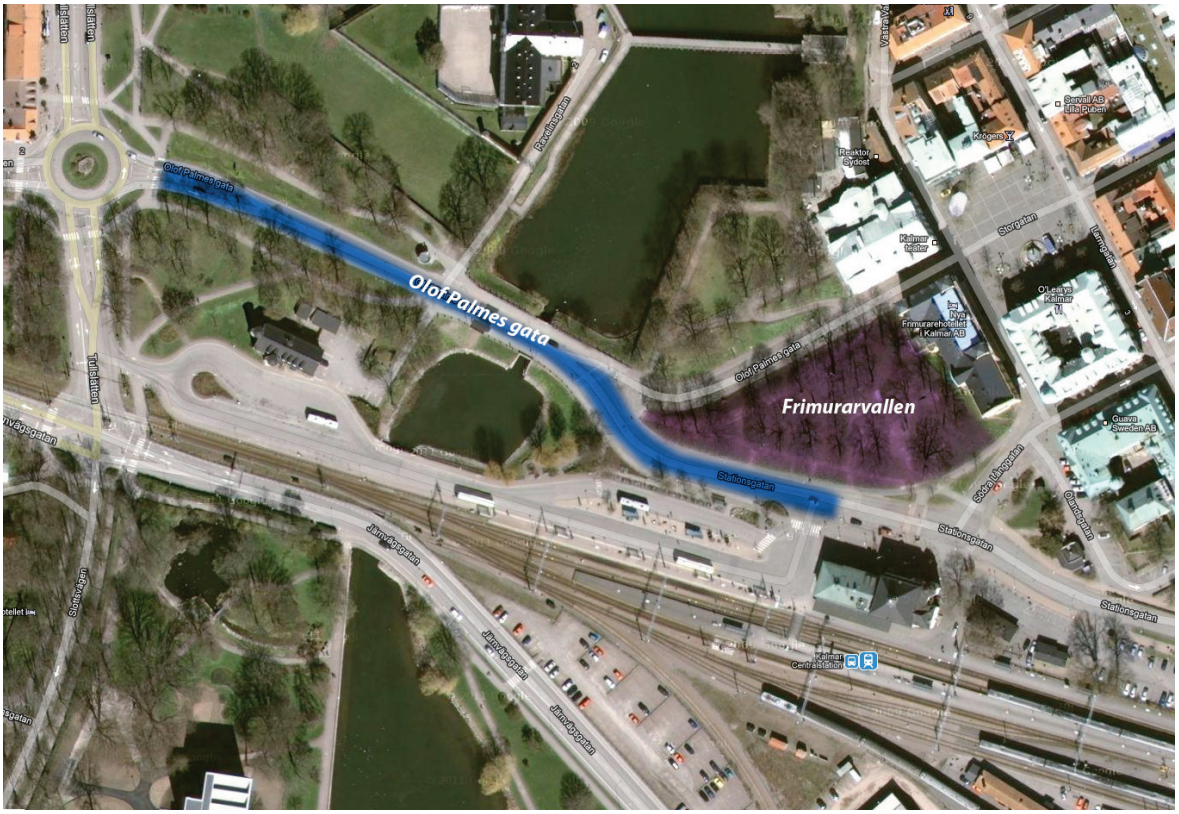
In Kalmar the aim was to show the possibilities to control LED light. The Kalmar team initially planned to make an installation showing that it was possible to have LED installed in sensitive areas. However, after many and long discussions within the municipality about the installation site, the team eventually decided to find other places for the installations. It was decided to spread fixtures in as many places as possible in order to make politicians, civil servants and citizens aware of the new LED technology. The result was six different installations.

The public procurement process began in November 2011, considerably delayed owing to the above mentioned internal discussions within the municipality about the installation site.

Kalmar has made LED installations in walking and biking areas and streets. Pilot installations had to be good examples of how LED technology can be integrated into existing environments in order to motivate the target group to make investments in LED technology.

Important aspects for the pedestrians in the testing areas should be:

- Easy to recognize people.
- Comfortable to enter the LED lighting area and experience it.



View from the opposite site of the road (daytime and nighttime).

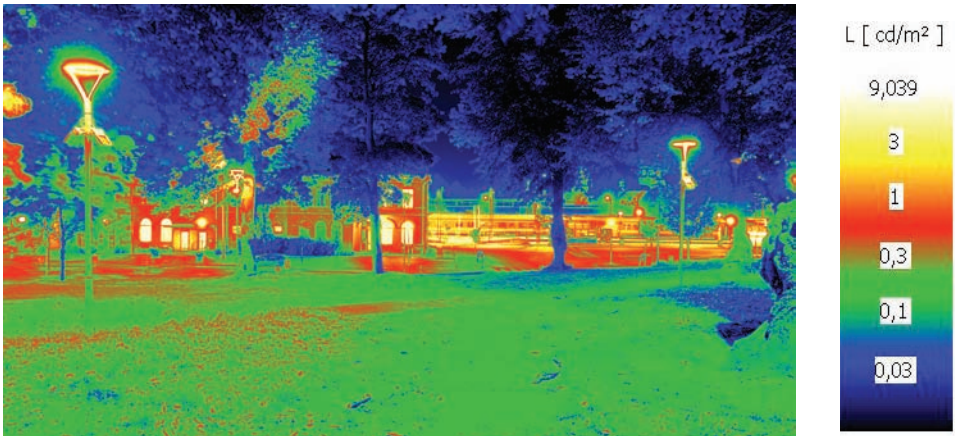
Frimurarvallen Park

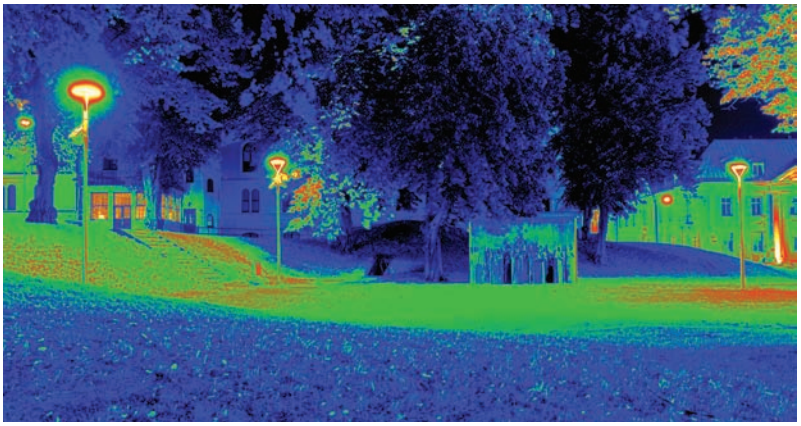
Frimurarvallen park is the first view that a visitor gets when arriving by train or bus to Kalmar. It is located opposite the train and bus station. It used to be a dark, rather violent place with poor lighting. The light tests, taken place in November 2010, showed that it is possible to make this site a lot more attractive.

The Kalmar team believes that the lighting set up in this point will stimulate a public discussion about the new technology. Another hope is that the installations could be used as basis for future plans, for both temporary and permanent installations.

The area is lightened up by LED luminaires that give a uniform illumination to the place. Moreover, led RGB headlamps have been installed on the same poles and they are directed to the trees. They are controlled and there is the intention of creating different control scenarios which will be used during different special event that take place in the city of Kalmar.

The below pictures illustrate the view of Frimurarvallen park from two different points. There was an evaluation of the luminance levels and uniformity of the areas via software and the results showed that the average illuminance is over the minimum level of the regulations.





Olof Palme's street

In this installation(images below), the old luminaires were replaced by the LEDs adding in the place the light quality of LED technology (higher CRI, better light distribution, lower energy consumption, etc.).

Lindö area

The Lindö installation consists of a road, two bridges and an underground passage for pedestrians and bicyclists, which previously had the old technology of mercury lamps. Lindö installation was planned to be a more design and playful installation. Light of course was well suited for pedestrian and cyclists and the below picture shows the road with the light installation that fulfills the needs of pedestrians, bicyclist and cars.

However, Kalmar's team wanted to deliver something more than this. One of the bridges was used in an effort to make the place nicer and more attractive to the public. Except from the necessary lighting for the road, it was decided to install RGB-LED fixtures on the bridge and create different light scenarios, using them when different events are taking place in the city of Kalmar.

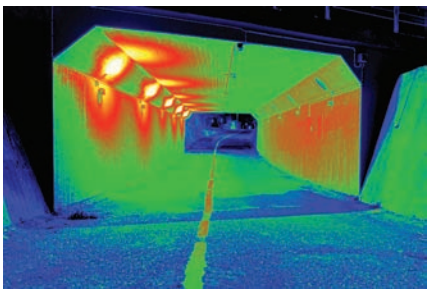
The installation consists of LED RGB-luminaires that lights up the facade of the stone bridge and white LED light that illuminates the vault under the bridge. They will be controlled according to the special events which are taking place at the city.

The intention is this installation be visible from the opposite side (both from Ängöleden and Kvarnholmen) calling the citizens and visitors to approach this area and experience it or pointing out that a special event is taking place in city (image on next page top).

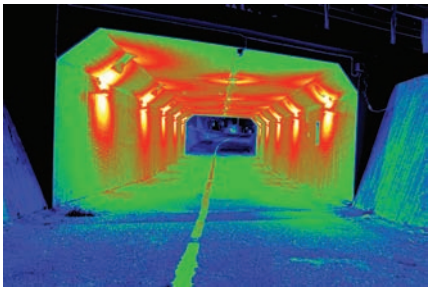
In the EU project, alternative ways to define energy-efficient lighting had to be demonstrated. A way to save power by using the new LED technology and interactivity. So in the same area, there is an installation of an underground passage for pedestrians and bicyclist where the lighting is more experimental with interactivity with the passengers (images on next page).

The tunnel length is approximately 17.5 meters, 5 meters wide and 2.7 meters high. The light concept is focused on the tunnel walls and ceiling.

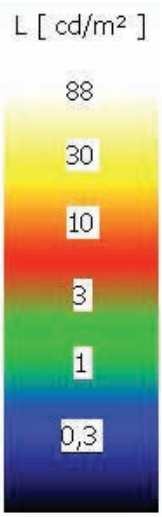
The lighting on the walls is always switched on during the hours of darkness (image below left). The lighting points of the roof are only switched on when someone passes the edges of the tunnel and then switch off after 5 minutes of nobody's presence (right picture).



Old light installation (mercury lamps).



New LED light installation.



Rinkabyholm

The cycle path linking Ljungbyholm-Rinkabyholm and Kalmar was partly illuminated. An unlit distance of about 3600 meters was replaced by a new installation of 120 points of light (placement of one light point every 30 meters).

When dimensioning lighting one must take into account two things. One is that the sectional area of the cable must be large enough to run the lights. The other thing is the short circuit condition. Through the use of current measurement, quite unique in Sweden, one only needs to size the sectional area for driving the lamps. Moreover, the use of copper cable leads to a less expensive installation due to the low losses of copper cable and a more environmentally friendly solution for the same reason.

With the above technique, we have also the possibility of measuring the consumption of the installation and detect light bulbs through the network. It gives the possibility to know if the lights are broken before the pedestrian knows that!

The LED lights that are installed in this area give a warm light of 3000 K and a CRI of over 80, so the rider perceived a cozy and welcoming atmosphere. The face of the people look natural and the grass, trees and shrubs are experienced vibrant and alive.

Regional aspect

The experience of this part of the project leads to a tendency to believe that the fixtures that the municipalities looked at is the result of a trend in which manufacturers tried to make a fixture in the easiest way to replace existing fittings.

The industry want to apply new technology with arguments like 'lifetime 50 000h', 'less maintenance', 'high purchase price covered by a long life', etc. This hides in some way the real benefits of LED's.

For example, the argument that LED can last for 50000 h, which is often used, is perceived as a good feature but this data doesn't give any information about the quality of the emitted light. Who wants a fixture that will last for 12 years when you know that LED technology is developing at a faster rate than that? Instead of that, the focus could be on how easy the fixtures could be replaced when the technology is updated.

Many manufacturers follow a design for fixtures based on the conventional ones in order to just replace the old light source by LED. A LED fixture should be developed from the beginning, trying to investigate the possibilities that LEDs give and not based on an old technology struggling by this way the quality of a new product. Unfortunately, a lot of fixtures in the market are built with this tendency without leaving space for more experimental lighting or lighting based completely on LED.

To control the light in a conventional light source has not been easy because it needs to combine electronics with analog light source. On the other hand, LED can be easily combined with electronics and control systems.

Conclusion

LED is a light source that brings change in the field of light. A general difference compared to the past. Working with LED is different from working with the old technology. This was something that was experienced during the interaction and communication between municipalities, planners and public through these years during which the led pilot installations of the project were delivered.

LEDs offer a better quality of light in comparison to the old light sources, better light distribution with greater uniformity as the project experienced in Frimurarvallen park installation in Kalmar.

It is a light source with a high colour rendering index (CRI) value. This was obvious by all the pilot installations of the project and mainly in comparing the old installation and the new one in the passage in Lindö, in Kalmar. This new technology offers a variety of different correlated colour temperatures (CCT) as it happens in the pilot installation at the schoolyard in Wismar.

Moreover, LED as a light source gives great possibilities in the design part. This was noticed in the recreational project in Gdansk during which luminaires were designed for the recreation of this area. It is also a RGB light source that can be controlled through and used in design projects.

As it was experienced through the pilot installations, LED is a light source that fulfills the demands of the standards and regulations about values such as light levels, brightness, uniformity, etc.

Finally, LED installations were undoubtedly in all the delivered projects an energy efficient solution. In many cases, such as in the project in Rostock, the municipalities can save great amount of energy due to lower energy consumption of leds, their qualities and possibilities that they offer.

Part four

What do we expect and need from the future?

Further Need for Research

FOR THE FIRST TIME IN THE HISTORY OF OUR CIVILIZATION, MAJORITY OF THE global population will be living in urban centres than rural areas. The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities.[1]

Urban landscapes are expanding and growing at an astounding pace to accommodate our ever increasing population, needs and demands. In order to have places that are lively, safe, sustainable and healthy, the ideas of social sustainability along with an open and democratic society needs to be developed and strengthened. One major step towards this is to focus on the human factor, reinforcing the social functions of a space by encouraging a compact city – with development focused around public transport, walking and cycling.

Lighting can play a very important role in developing these pedestrian environments. Light as we have read in the previous chapters is essential for creating a safe, visually comfortable and pleasant pedestrian environment.

The need and demand for better urban quality can be directly related to the improvements for people in an urban space.

Dynamic Lighting

If light can be considered to define space then dynamic lighting explains both time and space.

Technology today offers new ways of communicating and interacting with light. The digitalisation of our lifestyles has resulted in a scenario where we find all the information at our fingertips, communication and exchange of data is becoming faster everyday, boundaries are being redefined; all in all we are finding ourselves in the middle of a very individualistic society, in which we demand and expect to control each and every component of our life. Further on, this digitalisation is not limited to our private spheres and spaces anymore; it is finding its way into our public spaces and public life. The boundary between private and public space is very thin today, digitalisation and technology has made it possible for us to create our own private spaces in public spaces. Customisation and made to fit solutions are very easily achieved with today's technology.

Digitalisation of light is now a reality with LED technology; and this digitalisation enables a multi facetted control of light. We are able to control all the parameters of light, starting from:

1. Quantity
2. Distribution
3. Spectrum
4. Colour temperature
5. Timing
6. Duration

Giving us the opportunity to have the required amount of light, where it is required, when it is required, for what duration it is required and in what colour or colour temperature it is required. As LED technology offer complete control over such characteristics, light can be controlled and made to respond to changing situations, thus fulfilling multiple functions or variable functions at the same time.

Having such possibilities opens up new avenues in personalisation and customisation of spaces; visual environments can be modified and transformed with a push of a button. The omnipresence of light is suddenly under question, light that has been present even in the smallest of villages and now it is very easy now to manipulate or take away light all together.

It will be worth further research to examine this new possibility to take away light, to create customised and individual visual environments and to manipulate light according to the surrounding or the place.

An important question that arises is how much light can be taken away or modified without affecting the sense of safety and security? What sorts of modifications are possible that do not affect our visual acuity and visual comfort?

There is an interesting conundrum, technology and digital devices have transformed our lifestyles, allowing for individualisation and customisation in each and every sphere of our life; including public spaces and public lighting. But we are also faced with the question of energy deficiency and sustainability; having a situation where each and every one of us tries to have a visual environment that is based on our individual needs and demands will create increasing pressure on the energy required for such customisation.

Moreover, the infinite possibilities to control so many parameters of light by so many different users will result in complete chaos and anarchy. The possibility of increased control on light and increasing interactions with light can complicate our actions. Every user would want to customise light based on their needs. However, possibly technology can offer a solution for such a situation as well; we do find ourselves in the middle of an ever connected society, through internet we are constantly connected with the entire world. Combining such technology with sensors, cameras and previous preferences, lighting requirements could be predicted in advance, added to this, when such a solution can be combined for many users together, behavioural and preference patterns can be easily predicted. Customised visual environments can thus be created for a group of users in advance, without their active participation.

These are but a few examples, the rapid progress of technology is opening new avenues and paths; it will be of great public interest to study such developments in detail, trying to analyse the effect of customisation and individualisation on public lighting and how can we then bring these 2 very different aspects together. Also, how can we achieve energy efficiency whilst taking care of our individual needs and aspirations?

Dynamic Light control

The current and looming problem of climate-change, depleting resources and increasing population have given rise to concepts of sustainability, green technology and carbon neutral technologies.

One such concept for the future city is the carbon neutral city, it refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset. It is used in the context of carbon dioxide releasing processes, associated with transportation, energy production and industrial processes.

Central to such a concept is the use of energy efficient technology. Despite the rapid progress of LED technology in recent years, it is still only marginally better than the conventional technology.

For the optimum use of the LED technology an intelligent control system along with a dynamic lighting concept is essential. “Significantly more energy can be saved in a Lighting installation, when it is operated by an intelligent lighting control system”[2]

The dynamic lighting concept allows for reduction in energy consumption without reducing the quality of light.

Taking the example of Germany, out of the total 9.13 million streetlights majority are inefficient using outdated technology. More than 30% of the streetlights still employ obsolete technologies from the 1960’s and around 45% are still using mercury vapour lamps.

A simple replacement with LED technology is only a part of the possibilities offered by LED technology and will not help us achieve the goal of a carbon neutral city.

The LED technology offers the possibility to design complex control scenarios that can dynamically change the characteristics of the lighting with changing requirements, uses or needs. A very simple application of dynamic lighting is the control of illumination levels based on the user frequency. Other sensor-based approaches, which may in addition to intensity of use can include other parameters like brightness, contrast, light colour, daily, monthly and yearly time, weather and climate etc. This allows for each and every use or function can be designed with the correct light quality and maximum energy saving potential.

The LED technology allows the use of any sort of lighting control system and is especially useful for intelligent lighting control systems.

Light management systems are a rapidly developing technology and can provide the correct and required quality if light maximising the energy efficiency and reducing the overall energy consumption, further advantages of such systems include financial benefits, ensuring environmental sustainability along with economic sustainability. Some advantages include:

- Information on the condition, functioning and age of each light source will help in establishing accurate maintenance schedules.
- Monitoring of failed lamps, report on their location will help in minimising maintenance expenses in terms of materials, labour, routing etc.
- Tracking the hours of operation will provide valuable information on energy consumption patterns.
- All such information will eventually help in establishing an accurate life cycle cost calculations, cost benefit calculations that will help a city make informed choices and decisions.

The important questions here are the definition of the parameters and conditions for the dynamic control of lighting. Which parameters can be used to create the optimum visual environment? Which parameters are important and which can be ignored? Which parameters can be combined to create the optimum visual environment? Which external factors like user age, profession, taste, disability, like and dislikes effect the parameters?

But more importantly, the effect of dynamic lighting on the use of nocturnal environment needs to be further studied. We need to understand the effect of such changes in light quality on the physiological and psychological conditions of the users. We have been accustomed to stable and constant light levels, how will we react and adapt to the dynamic and changing light qualities?

LED technology allows for synergistic benefits. LED technology can be conceived as part of a larger intelligent network. Grids and networks of luminaires that will be able to exchange information with other services like traffic, emergency, telecommunication systems and security systems. A city of the future will need to be able to see, hear, smell and react to the different scenarios, a truly living city. Technologies like LED can play a vital role in these future cities, efforts should be made to explore the different ways in which LED technology can be used with the other developing technologies to develop a city of the future that is energy efficient, self sufficient and provides optimum living conditions. We need to look at solutions that will provide environmental sustainability, economic sustainability and social sustainability.

Light at night as Zeitgeber

The strongest “zeitgeber” is light. But due to our contemporary human behaviour and our 24 x 7 lifestyle, days, month and seasonal time cycle are losing their significance. The ever-connected society, late-night shopping, round-the-clock public transportation, shift work and an attractive night-life are liberated us from the day/ night rhythms. As a result, internal clocks, synchronisation between humans and the environment are disturbed.

LED with suitable lighting control can once again reinforce or support these time cycles. Dynamic white light with varying colour temperatures can mark the different times in a day, giving a visual clue to the individual about the time of the day.

Effects of light at night

Broadly the effect of light on humans can be divided into three categories: visual, psychological and biological. The biological and psychological effects of light at night have been and are in the focus many studies. Several disciplines like chronobiology, ophthalmology and psychology have contributed to our current knowledge about the effects of light on circadian rhythms, health and well being. Despite the progress in this field we still do not fully understand the effects of light, a number of questions remain unanswered. The effect of exposure of light at night on human beings should be researched further.

Some of the main areas of discussion and investigation that are critical to understand the effects of light at night are as follows:

a. Spectral composition of light

A number of studies have been and are being carried out to understand the effects of different spectrums of light on the human health and well being. The discussions of the topic of light at night as it may affect the biological and psychological state of humans has to include the temporal – spatial - spectral distribution of optical radiation incident on the retina together with corresponding temporal – spatial – spectral and absolute sensitivity of the human circadian system.

The use of more white light in the nocturnal urban environment will lead to the presence of particular spectrums of light which are not usually present during the dark hours. The effect of such spectrums of light needs to be investigated, but keeping in mind the time of exposure to such spectrums. Many previous studies have found link between certain light spectrums and hormonal secretions, but attention needs to be paid to the amount of time the eye is exposed to such spectrums. In a nocturnal environment, we tend to spend far less time as we might tend to do in say an office environment.

Due to the lack of in-depth research in this field it is premature to jump to any conclusions. Thus it is critical to study the effects of different spectrums of light at night along with the exposure time.

b. Light distribution in the visual field

The effects of light distribution in a visual environment have also been under many studies, but still the spatial experience created by lighting is not fully understood. It is important to know how people experience designed night time space in order to design night-time urban spaces.

The human mind scans the surroundings for an overall view of the surroundings, searching for visual cues to develop a mental image of the surroundings.

Standards and Guidelines

Today we find ourselves in the middle of relative conditions between the human being and the living environment, from flexible working places and time to changing lifestyles. The standards and regulations are usually absolute in nature; the regulations need to be adapted to the changing lifestyles.

Current standards have been developed with conventional light sources, there should be an investigation into what sort of changes and modifications are needed to accommodate new lighting technology like LEDs.

Further on in urban centres, due to the large number of vehicles, the speed of movement is usually low and on top of this there is a large amount of reflected light from the headlights of the vehicle.

The effect of headlights and low speeds in the urban cities could be utilised to reduce the amount of light on roads in urban centres. Thus in busy urban centres with increasing traffic, the light levels required for the safe movement of the cars could be reduced, eventually lowering the energy consumptions. However, such developments should take place only after proper and thorough research.

In addition, the effect of different luminous surfaces and varying reflective properties of various materials in an urban space have an effect on the complete visual environment. Further study is required to understand the effects of such varying luminous surfaces and the energy savings that can be achieved by utilising them.

Having light where it will be most beneficial effect in reducing fatalities and personal injury accidents[3]. It would be worth investigating whether the recommendations for road surface luminance at the low end (slow movement traffic) are insufficient and the recommendations for the high end (motorised traffic movement) are excessive. If it is the latter significant energy savings can be made by revising the standards.

Master planning of light

Creating cities, towns and communities that are economically, environmentally and socially sustainable, and which meet the challenges of population growth, migration and climate change will be one of the biggest tasks of this century.[4]

The urban realm today is confronted with challenges never witnessed before, coping with overcrowding, pressure on housing and transport systems, climate change and ageing societies, changing behavioural patterns bought on by new technology and media; added to this the impending energy crisis and environmental disasters.

Through urban planning and design, architecture, public policy research, housing management, community development and local government participation, using different languages, professional approaches and ideas we are constantly trying to evolve solutions that can overcome all these challenges.

There is a vast amount of knowledge available on how the physical environment – urban spaces, architecture shapes human and social behaviour and people's sense of place; how high quality, well maintained public spaces influence perceptions of personal safety; the role local green spaces play in wellbeing; and how to design out crime, also how local identity and social networks influence people's feelings of attachment and belonging to places.

Our perception of the nocturnal urban environment depends on a number of elements in the environment; light amongst them is the most perceptible and influences the visual perception to the maximum. Light is now accepted as a strategic tool for urban planning, it is being considered as an instrument and a tool for urban planners, designers and architects in providing sustainable and hospitable cities of the future.

Lighting master plans function as structured guidelines for cities on how they can develop their lighting installations to high qualitative and energy efficient lighting. The goal of a lighting master plan is to have well designed good quality light within an integrated lighting and urban structure that is in direct reference to the character and spirit of the nocturnal city.

A lighting master plan can present unified lighting strategies that help improve the area's attractiveness after dark, enhance important heritage and tourist landmarks, make the public space safer and more exciting, help promote the night-time economy and at the same time improve the environment.

Lighting accounts for nearly 6% of global CO_2 greenhouse gas emissions, or 1,900 million tons of CO_2 per year that is the equivalent of CO_2 emissions from 70% of the world's passenger vehicles.

We can make a considerable dent in carbon emissions if we make lighting a lot more energy efficient.

On top of this providing street lighting is one of the most important - and expensive - responsibilities of a city: Lighting can account for 10–38% of the total energy bill in typical cities worldwide (NYCGP 2009). Furthermore inefficient lighting wastes significant financial resources each year and poor quality lighting creates unsafe conditions that not only result in deterioration of the public space but adds to the financial burden on a city in terms of increased vigilance, policing, surveillance cameras, insurance costs etc not accounting for the emotional and psychological impacts of crime. All these factors are resulting in the increasing demand of the municipalities for energy efficient lighting solutions and effective lighting strategies.

Unfortunately, many municipalities, towns and cities are far from adapting or implementing energy efficient directives and solutions.

The main barriers for acceptance are scepticism, lack of knowledge, outdated government policies, procurement rules, and higher capital cost of new technologies with long payback periods.

Also a very critical factor in the lack of implementation of sustainable practices is the fact that with the introduction of new energy efficient technologies, more sophisticated methods of planning and design are necessary to make use of the possibilities to reduce the energy consumption of public lighting.

These new possibilities in planning and design have to be understood before lighting installations can be updated with the aim of reducing energy. Lighting master plans can ensure the implementation of sustainable and energy efficient solutions that create good quality lighting and visual environments.

The differentiation in lighting is increasing, which requires new planning steps that have to be implemented in the planning of public lighting.

As the new technologies are based on systematic new approaches, punctual changes will not solve the problem of high energy consumption. An essential market barrier is the wide spread of scepticism and the lack of knowledge among town planners, administrative staff, technical experts and decision

makers about the technical requirements and benefits of energy effective lighting solutions. These potential users of energy efficient urban lighting need to be more aware of the assets of the new technology. Additionally it is important that they gain knowledge on what the limits are and how the urban areas should be planned in order to get the best and most efficient light.

It is paramount to guide, raise awareness and build technological and technical capacity between the various groups involved in urban lighting schemes. This will foster a better understanding of energy-efficient lighting technology and the way how to use it, eventually giving authorities the confidence and encouragement to implement such technologies.

There is also the urgent need to permanently include energy-efficient lighting into urban planning (lighting plans integrated in Sustainable Energy Action Plans) thus strengthening the public authorities in the field of sustainable energy planning and implementation in city lighting.

The lighting masterplan need to guidance on the broader implementation of the lighting treatments, covering issues such as technical requirements, aesthetic aspirations, lighting management and control systems, light pollution and maintenance methods.

Urban Regeneration

Light contributes in multiple ways to the constitution of a city. Apart from the reflexive quality mentioned above, light affects us on the level of physical as well as symbolic perception. Taking into account the potential impact of lighting on our bodies, behaviour and social interaction, it can be assumed that illuminating urban spaces differs significantly from other means of urban renewal, such as new paving or street furniture.

By taking into account the local sense and use of place, lighting might trigger new ways of looking at everyday spaces, to engage with them in an imaginary or practical way, and thus encourage new urban design solutions.

Effective urban lighting can provide safer cities, highlight national monuments and landmarks, create beautiful and stimulation sights and give boost to the night time economy.

Any urban regeneration project needs to be centred on the people that use the space, it is fundamental to understand the layout, function and activities taking place in the area. Moreover, the involvement of the local community has been proven to reduce levels of vandalism and crime.

Some of the ways in which light plays a role in urban regeneration strategy are:

1. *Ambience*: the way we perceive our nigh-time environment is almost totally dependent on light. Light can generate feelings of invitation and warmth, intimacy or spaciousness, or even excitement and drama.
2. *Identity*: Each and every space in an urban environment has its own individual identity, character and spirit. Lighting can reveal or enhance these aspects
3. *Safety and security:* Light is essential for safe movement and for increasing the feeling of safety at night.
4. *Orientation:* Light helps in better readability and understanding of the city, it enables us to see where we are, where we have to go. It helps us in understanding our surroundings.
5. *Promotion and spectacle:* Light is an effective means of publicity and promotion. It can be a source of entertainment, amusement and recreation in an urban space.
6. *Night-time economy:* the local economy can benefit from the extension of business hours, attract tourists and encourage revitalisation of communities.

In an urban regeneration programme in Philadelphia, United States, a Center City District (CCD) was established covering 220 city blocks and over 5000 properties. Philadelphia suffers from the problems of decreasing population, rapidly declining economic activity leading to deterioration and abandonment. In addition poorly maintained public environment has resulted in the steady relocation of the businesses to the surrounding suburban areas. The programme was started to rebuild the public confidence in the city and encourage business and residential growth and reinvestment within the district. The programme included strategies to upgrade the public environment, improvements in street light-

ing, street furniture, signage etc. The focus of the redevelopment had been the needs of the people, the economy and the environment.

Through a strategic improvement of night-time lighting of the city, the social needs were addressed by creating a safe and attractive environment. Since 1997, CCD has installed over 2100 new street-lights, relighting 65% of the all the streets and also created 2 special lighting zones within the district.

The effect of CCD's programme has been positive and measurable. Soon after the completion of the initial street lighting programme, residential population began to increase – 25% since 2000. The psychology of decline has given way to a sense of renewal and excitement, and a vibrant downtown night life. The population increase has included a dramatic growth in the number of young professionals and young families with children, important signs of the economic regeneration of the district.

The rebirth of the Centre city is also reducing the carbon foot print of the region – 40% of centre city residents walk to work.

The strategic use of light, along with other programmes, has encouraged the re-use and improvement of buildings and infrastructure that have been dedicated to urban development for centuries.[5]

On the other hand, the design of cities from the point of view of the tourist or for purely commercial benefits, can lead to the situation where light creates segregation between the society, division between those who can afford to enjoy the night time economy and those who cannot.

The 24 hour illuminated city can have its own negative aspects, encouraging a 24 hour lifestyle and increased night life, can lead to undesirable situations of alcoholism, drug abuse etc.

Endnotes

1. Department of Economic and Social Affairs, United Nations (June 2009) Population newsletter, available at: http://www.un.org/esa/population/publications/popnews/Newsltr_87.pdf accessed on 14 September 2010
2. *Licht* magazine, LED in der Strassenbeleuchtung, 1-2, 2011
3. Lighting for Driving: Roads Signal and Signs, Vehicles, Boyce PR, 2009
4. Design for social sustainability, Saffron Woodcraft with Tricia Hackett & Lucia Caistor-Arendar
5. Lighting as a catalyst for urban development, PLDC 2009, Alfred Borden and Paul Levy

Appendix articles

When producing this report the LED Light in Public Space project also commissioned a number of academic writers to contribute with additional ideas and discussions. These articles are published in the report Appendix, which can be found and downloaded on the project's website.

http://www.ledlightproject.eu

The following articles are included in the appendix:

Light Possessiveness and Light Contemplation, by Marco Ludwig.

LED - Optics or Reflector, by Uwe Rabenstein.

Retrofit, by Uwe Rabenstein.

Business Case of LED Luminaires, by Uwe Rabenstein.

Role and Importance of Public Lighting, by Saurabh Sachdev, Peter Schmidt and Thomas Römhild.

Lighting Masterplans in Cities, by Ulrike Brandi.

Ligting masterplans as Instrument for Municipalities, by Dennis Köhler.

The Plan Lumière – Lighting concept for the Swiss City of Lucerne, by Mario Rechsteiner and Maren Schmermund.

Product Abilities and Standards, by Eleonora Guseinoviene, University of Klaipeda.

User's Needs and Demands in Different Environments, by José Nuno Pinto de Sampaio Fernandes, Effrosyni Stragali and Jan Ejhed, Linnaeus University, Peter Schmidt, Hochshule Wismar University of Applied Sciences and Stasys Paulauskas, Public Institutiion, Strategic Self-management Institute.

Market Analysis, by José Nuno Pinto de Sampaio Fernandes and Jan Ejhed, Linnaeus University.

Standard Development for Public LIghting, by Effrosyni Stragali and Jan Ejhed, Linnaeus University.

Inventory of Design Solutions, by José Nuno Pinto de Sampaio Fernandes and Jan Ejhed, Linnaeus University,

Design Development for Specific Areas and User Types, by José Nuno Pinto de Sampaio Fernandes and Jan Ejhed, Linnaeus University.

Development of Design Manuals for Planners and Manufacturers, by Effrosyni Stragali and Jan Ejhed, Linnaeus University,

Also included are the project Activity reports:

KHES1 The First Know How Exchange Seminar in Klaipeda, as responded by Linnaeus University, Kalmar, Sweden and University of Klaipeda, Lithuania.

KHES2 The Second Know How Exchange Seminar in Kalmar, as responded by Linnaeus University, Kalmar, Sweden.

Additional material may have been added following the publication date of this report. Please check website for accuracy.

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