BLISS

Better Lighting in Sustainable Streets

BLISS
FINAL GUIDE

Volume I

Better Lighting in Sustainable Streets

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Preface

The Better Lighting in Sustainable Streets (BLISS) project was instigated in 2009 to address the need to reduce energy consumption in public lighting, which would help municipalities meet their obligations to reduce carbon dioxide emissions. The BLISS partners St. Helens, Eindhoven, Interleuven and Kaiserslautern.

The United Nations Climate Change Kyoto Protocol, the Lisbon and Gothenburg Agendas for growth, jobs and sustainable development, the European Climate Change Programme and the policies of European Member States to reduce carbon emissions by 20% by 2020 and 80% by 2050, were key drivers for the BLISS project.

The threefold increase in the price of energy between 2005 and 2010 and the world economic downturn in 2008, gave an additional impetus to the project. Unless municipalities could find ways to reduce energy consumption, they would struggle when faced with budget cuts and conflicting priorities to find the funding to keep public lights switched on. For all these reasons, BLISS was needed to investigate how street lighting could be delivered with improved energy efficiency.

Many projects across Europe have looked at how to reduce energy consumption in lighting. These projects were mainly driven by the increasing cost of energy. However, these projects looked only at street lighting efficiencies and not at the impact that reducing (or turning off) the lighting would have on crime, accidents and the citizens' and users' perceptions.

That is what has made the BLISS project different to most other lighting energy saving projects. We have undertaken consultation with local residents and wider stakeholders both before and after the installation of energy saving measures, to gauge their acceptance. Similarly, we have critically examined crime and accident figures, to ascertain whether the changes to the lighting have made any impacts.

Most of the procedures and techniques that we have used have been successful, but not all. The partners have tested a diverse range of energy saving techniques in a variety of different situations and environments. These include major high speed roads, distributor roads, roads in residential areas, industrial estate roads, town centres and parks.

We have embraced the most modern technology, including Light Emitting Diode (LED) lighting, incorporating variable lighting levels both stand alone and centrally managed.

We have also undertaken low cost simple 'retro-fit' replacement of inefficient control gear and replaced light sources with a reduced wattage "white" light, achieving energy savings of over 40% with a return payback of five years.

The Guide looks to the future and makes the case for considering the "Total Value of Ownership" when assessing the cost and benefits which lighting can make to a project. This may help municipalities make a better business case to justify future investment and expenditure on lighting schemes.

BLISS demonstrates that significant energy savings can be made by selecting the appropriate lighting and controls, and that reduced energy consumption can be achieved without causing adverse impacts on crime or accidents and still satisfy citizens and stakeholders expectations.

The BLISS Technical Case Studies (TCS) support this guide and are available on-line. These illustrate how energy savings of 40% to 80% were achieved.

BLISS Technical Case Studies

St Helens;

http://www.sthelens.gov.uk/what-we-do/traffic-travel-and-parking/highways/street-lighting/BLISS-case-studies

Eindhoven:

http://www.light-s.nl/website/light-s

Interleuven

www.interleuven.be/bliss

Kaiserslautern:

http://www3.kaiserslautern.de/wb

Acknowledgements - Interreg IVB Programme

The Partners express their appreciation to the INTERREG IVB North-West Europe (NWE) programme for giving approval for the BLISS project and also for the continued support which the Partners have received for the duration of the project.

Transnational projects can be difficult to co-ordinate and manage and the assistance from the Joint Technical Secretariat (JTS) was instrumental in ensuring that the project ran smoothly. The project has enabled the partners to trial and collectively review the effectiveness of a range of new and innovative products and techniques which would not otherwise have been possible through their normal programme of works.

The BLISS project is disseminating information to a large number of other organisations and has acted as a catalyst to inspire others to embark on their own energy saving programmes. If the BLISS project had not been funded through the INTERREG IVB programme, the different techniques and technologies would not have been trialled and innovation would have been stifled.

This guide follows from the lessons learnt from a number of previous and ongoing important projects including: the Public Lighting Strategies for Sustainable Urban Spaces[1] (PLUS) project, set up to assist cities to develop their lighting policies and strategies in order to implement energy efficient lighting solutions; Energy Saving Outdoor Lighting[2] (ESOLi) project which increased the awareness of intelligent public lighting technologies; Intelligent Road and Street lighting in Europe[3] (E-street), which set out to expanded the market for energy efficient street lighting; Streets for Living[4] (STRING), which examined Social Inclusion, Crime and Safety and the Street Environment and Efficient Lighting for Developing and Emerging Countries[5] (en.lighten) which list of projects has been established to promote, accelerate and coordinate global efforts to push for efficient lighting. The project has also had regard to the procurement of the ENIGMA project[6] .

The BLISS project provides assistance to municipalities wishing to reduce energy in public lighting and gain the support of citizens. We would like to thank you for your interest in this guide.

The BLISS partners,
St. Helens, Eindhoven, Interleuven and Kaiserslautern.

1 *http://www.luciassociation.org/plus-workshop.html*
2 *http://www.esoli.org*
3 *http://www.e-streetlight.com/*
4 *http://www.livingstreets.org.uk/*
5 *http://www.enlighten-initiative.org/*
6 *P.7 http://www.ili-lighthouse.nl/Images/20131219ENIGMADeepDiveReportLRspread.pdf*

1. The Partners

1.1 Focus of the Project; The BLISS Aim

The aim of BLISS was to assess how tailored design techniques and energy saving products could reduce energy consumption in street lighting using across a range of highway scenarios. At the same time partners have assessed the impact of installations on crime and accident statistics, (citizens) perceptions and on socio economic indicators.

BLISS partners haves assessed the benefits of a broad spectrum of existing energy reduction techniques including the use of energy saving light sources including Solid State Lighting (SSL), varying switching times, dynamic lighting control and the application of variable lighting levels.

Many citizens believe that "better" public lighting needs increased levels of illumination – and that this will help prevent crime, and reduce the fear of crime, antisocial behaviour and traffic accidents.

BLISS partners anticipated concerns and questions from citizens and stakeholders in response to some of the proposed approaches and techniques. Partners wanted to understand, examine and then be able to challenge citizens' beliefs and preconceptions and to overcome misunderstandings so that public lighting authorities are more widely equipped to manage potential antagonism and objections.

Partners have been able to reduce the energy consumption of public lighting through simple low cost retro fitting techniques as well as examining the role of intelligent dynamic lighting control. We have been able to negate anti-social behaviour through the use of coloured lighting whilst at the same time putting energy back into the supply grid. We have glimpsed into the future with solid state dynamic lighting and the potential for this to contribute to the development of a connected SMART city concept. We have encouraged energy suppliers to make a paradigm shift towards providing what the citizens actually want!

These outcomes are now proven and are applicable to the rest of Europe!

1.2 Kaiserslautern

Kaiserslautern developed an appetite for innovative lighting during the 2006 football World Cup when more than 20 light based events were held and a new lighting installation along of boulevard of over 1.5 Km was installed. Citizens and politicians recognised the benefits of coloured and dynamic light and how illumination can be used to both promote the town and to address social and environmental problems. As the minor partner in the BLISS project, the town

Kaiserslauterns coloured lighting scheme. (TCS 10) has made a single investment to explore how coloured innovative lighting can solve localised graffiti and behaviour problems. Whilst the investment in small in nature it is important in the wide BLISS context as it merges the use of colour, dynamic lighting whilst off-setting the impact on energy consumption by generating electricity through the use of solar panels.

Multidirectional PIR & intelligent coloured lighting scheme. Kaiserslautern. (TSC 10)

Fibre optic backbone installed at Strijp-S as part of the living lab for light innovation (TCS 6.1)

1.3 Eindhoven

Eindhoven presents itself as the Dutch 'City of Light' and has been at the forefront of lighting innovation and manufacture since the late nineteenth century. It presents special lighting effects for all kinds of outdoor and public objects (buildings and works of art, as well as public parks and gardens), and in projecting images and poetic texts. 'Light-S' (at the former Philips Strijp-S site) is creating a new public lighting experience – citizens are active users of public space that must be enabled to influence their own experiences. They are empowered to create new experiences for the moment. Light-S includes 'Living lab' research that encourages new forms, interactions and applications of light. Strijp-S is about constantly experimenting and learning. This leads to new experiences and insights and a valuable contribution to Eindhoven's power to innovate. Within Light-S, different projects investigate how lighting can be applied to create new urban experiences, applying innovative techniques in a dynamic and spatial context. All lighting projects of Light-S fit within the vision, guided by the same conceptual, spatial and technological framework, in which enhanced experience through sustainable thinking is considered key. Light-S applies innovation across design, social and technical areas, making Light-S a truly unique initiative.

Houtemstraat Tienen (Interleuven).

1.4 Interleuven

Interleuven coordinates the work of their 30 municipalities towards the commitments of the "Covenant of Mayors" [7]. The BLISS project has been central in identifying the range of possible initiatives and policies for the 30 municipalities "Strategic Energy Action Plans" (SEAP) that will be prepared during 2015. Energy management will be an important part of SEAP process to ensure Interleuven municipalities meet the European Climate Change Programme and the policies of European Member States objectives. The BLISS experience and knowledge will assist in shaping forward thinking aimed at increasing energy savings in public lighting as part of the deployment of new lighting schemes which will be appreciated by the citizens whilst positively impacting on crime and accident data.

7 *http://www.covenantofmayors.eu/index_en.html*

1.5 St. Helens

St. Helens Council produced a "Carbon Reduction Policy" document in 2008 to ensure that the Council would achieve the national carbon reduction target of a 20% reduction on CO_2 emissions by 2020. Public lighting was identified as consuming almost 30% of total energy consumption by the municipality and it has been a key target to reduce this value.
The BLISS project has enabled St. Helens to test a variety of approaches and techniques in different situations which have all produced varied levels of energy savings. The Technical Case Studies detail how these savings have been achieved.

The investments undertaken in the BLISS project have identified the best approach to be taken to save energy in different situations. The success of the BLISS project has been the catalyst for the Council to embark on a € 2million "Invest to Save" public lighting project and has given the municipalities public lighting department the confidence to instigate a programme that will see 2.000 LED luminaires installed in residential areas, luminaires refurbished, and new lighting provided and a Central Management System installed along major traffic routes. The programme is intending to save € 260,000,- in energy costs (over 20% of the current annual street lighting energy cost of € 1.5 million) and payback the investment cost in less than 8 years.

St Helens Stadium Bridge.

1.6 The Partnership Approach

The four partners wanted to examine different approaches and techniques and test innovative techniques for reducing energy consumption. Each partner has explored different facets of the project with the experiences being shared and further developed within the Partners' areas.

St. Helens explored a range of energy saving techniques for different situations, concentrating in the main on the adaptation of its existing public lighting asset. St. Helens produced a methodology to evaluate stakeholder's perceptions of lighting. Refined in the early years of the project, this tool has been adopted and adapted by other partners to also objectively assess the performance of lighting schemes. The Partners developed extensive procedures to engage with the public to determine their acceptance of the energy efficient measures implemented.

Eindhoven has been at the forefront of innovation, working with designers and lighting / control system suppliers to develop lighting systems which are both energy efficient and will deliver high technological added benefits in the future.

Interleuven has been a first mover in Belgium testing innovative lighting systems and controls across a range of villages and towns.

Kaiserslautern experimented with using coloured lighting to assist in deterring anti-social behaviour, whilst 'off-setting' the increase in energy consumption through investing in generating power from solar panels.

Technicians, designers, engineers and politicians in each of the partners have learned and advanced their knowledge through the transnational working involved in BLISS. This sharing of techniques and experiences has been essential to the success of BLISS.

During the initial stages of the project a wide selection of LED luminaires were evaluated using a range of techniques including desk top studies, questionnaires, workshops, supplier dialogue, on site pilot assessments and resident consultation exercises. A review of independent research, undertaken in Belgium and the UK, was included. The research assessed light source characteristics and power consumption data produced by manufacturers. The results of the evaluations gave partners confidence when designing a series of installations using a range of different LED manufacturers equipment.

1.7 Engaging our Citizens

Public lighting is perceived to be an important instrument in discouraging crime and anti-social behaviour: preventing traffic accidents, promoting economic development by extending productive time, as a tool in creating places and even inspiring citizens.

Partners have engaged with citizens from disadvantaged communities through to aspiring new social entities in regeneration zones to show that reductions in energy consumption **do not result** in a rise in crime and anti-social behaviour.

Through mass questioning techniques, targeted focus groups and on site acuity testing across a range of demographics we have been able to understand citizens' fears and aspirations. We have involved them in shaping their own community through the concept of "democratic design". It has been well received and been a rewarding journey. We have ultimately been able to close the paradox between the requirement for energy reduction and the desire for improved lighting.

Working transnationally means lighting has been installed in different areas, using different techniques and, in different operating conditions – this means the conclusions are robust and transferrable within Europe and beyond.

In addition to the two volumes of the final guide partners have a wealth of technical information and citizen feedback to share – please contact us if you are interested.

1.8 Testing and Comparing

Partners tested and compared the results from many and diverse techniques and approaches. These included relatively simple cost effective adaptations such as replacing inefficient magnetic control gear with electronic alternatives and varying the time that lighting switches on and off through conventional switching methods (Trimming). Partners also tested the introduction of Solid State Lighting (SSL) luminaires and independent / connected intelligent lighting systems that vary light output and have other interactive functionalities including being capable of responding to public safety concerns. The Belgian energy distributor EANDIS, which coordinates the transition to SSL street lighting for many Flemish municipalities, has played an active role in support of Interleuven and in the sharing of learning. Together with other Belgian grid operators they test a wide range of components, and recommend installation specifications for Belgian partners.

Jef Scherensstraat, Wechter, Rotselaar. (Interleuven)

Testing and comparing installations has been across the range of highway and urban/rural lighting situations and with citizens from a diversity of socio-economic backgrounds and demography.

1.9 Approaches and Techniques

In terms of technological innovation, the project has undertaken initial desk top evaluations to assess the 'market readiness' of various new and emerging technologies which led onto a wide ranging investment programme to further evaluate some of today's most advanced sustainable techniques, including concepts yet to come to market, which have been developed within the frame-work of the BLISS project including;

- **Reduction in energy consumed**: Re-evaluation of lighting level classification & illuminated signage requirements, retro fitting of intelligent control gear, energy efficient lamps, photo cell trimming and standalone light output variance techniques.

- **Central Management Systems:** dynamic adaptive lighting control, variable lighting levels and connectivity external sensors and data sets to assist in the development of a SMART City concept through the interaction with other managed networks (e.g. traffic movement, parking, transport and weather)

- **New light sources technology:** white light: ceramic metal halide (CMH), light emitting diodes and **electro-luminance:** Eindhoven researched various ways of light emitting materials and their use including a pilot investment in phosphor luminance coatings. These reflected and emitted light and promoted a prototype using LED to charge the coating, and phosphor coating to emit the light through the clear acrylic glass. True electro-luminance techniques were too expensive to use in the prototype.

1.10 Transnational Monitoring and Evaluation

Partners have invested in gathering data on indicators (e.g. vehicle accidents, crime, social acceptance) before, during and after the investments. Where objective data has been available partners have compared this with citizens perceptions and other subjective data.

This joint partner effort has culminated in this guide: helping the reader understand the potential of energy saving lighting approaches and techniques across a range of highway scenarios, and how this can be guided by both the aspirations of the municipality (e.g. budget, asset profile) and demands of stakeholders.

BLISS mark


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which offers greater comfort, safer environments
and improves everyday urban life.
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Portiersloge Strijp-S Eindhoven, symbolizing the triple- and quadruplehelix cooperation

2. Responsibilities

2.1 Stakeholder Engagement

The BLISS project has revealed how important is to understand the roles and responsibilities of all stakeholders in public lighting. With this understanding, investments can be made that are efficient, cost effective and that reflect the needs and aspirations of our communities.

For any planned changes to the lighting in municipalities, engagement with stakeholders and citizens is essential for securing social acceptance.
Such engagement should be a key factor at all stages of the process, from the initial planning stage through to post deployment system evaluation.

"Lighting the Cities" [8] advocates stakeholder engagement in the planning, deployment and evaluation phases. The BLISS project partners have adopted this approach and the conclusions and learning are presented in section 5 of this guide.

The BLISS project partners used stakeholder analysis and mapping to design bespoke consultation and engagement strategies for each investment (see TCS). This identified that the responsibilities for public lighting are shared between a diversity of stakeholders including;

- **Technical and professional:** Lighting designers/engineers, equipment manufacturers / suppliers, economists, politicians, ecologists, highway engineers, infrastructure engineers, communication / hardware / software engineers, distribution network operators / energy companies, maintenance contractors and emergency services organisations.
- **Citizens:** local residents, businesses, cyclists, motorists, pedestrians, public transport operators, taxi drivers, tourists - recognising the different needs and interests of children, adults and the less mobile.

Well organised stakeholder involvement is looked upon as one of the main success factors according to Eindhoven, the most promising, fast developing dynamic top technology region in Europe. This so called 'Brainport Region' has a unique environment, which fosters crucial cooperation and open innovation between industry, knowledge institutions and government (triple helix) and the Brabant region: with a prominent role for universities. From the conviction that real innovation should be the outcome of full interaction, a new role is now inserted for citizens. With this quadruple helix concept Eindhoven is taking the next step in fully open innovation.

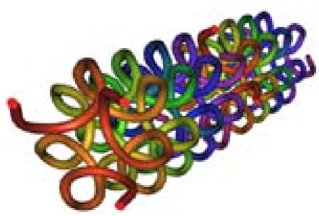


Figure 2.1 Triple and quadruple helix

8 Lighting the Cities. June 2013 EU ISBN 978-92-79-28466-3

This chapter is focussed on illustrating the benefits of understanding the roles and responsibilities for public lighting and how this can help to improve both involvement and stakeholder acceptance.

2.2 The Decision Makers

Who is 'in charge', or who takes the important or final decision on a lighting scheme depends on who you ask – politician or officer, technician or finance officer. But deciding which energy saving application is appropriate can involve few stakeholders or many. Each of the BLISS partners has very different political, administrative and technical frameworks within which they have taken these decisions and implemented their energy saving lighting investments. These frameworks influence the investment decisions;

- **St. Helens** is an autonomous municipality with elected politicians responsible for public lighting. It has a staff of 5 lighting professionals who design and manage lighting installations within the municipality extents.

Wetenschapspark Arenberg ,Leuven

View from Stadium Bridge, St. Helens

External contractors undertake the installation and maintenance of street lighting on behalf of the municipality. All expenditure associated with public lighting including capital, revenue and energy costs are funded directly from St. Helens municipality budget.

- *The St. Helens BLISS investments considered the aspirations and wishes of citizens and the social and environmental benefits of energy efficient lighting solutions. The technical design and evaluation was carried out by internal staff aided by external consultants as required. A specialist consultant was appointed to assist in carrying out the consumer research aspects of the project.*

- **Interleuven** is an inter service organisation established by the municipalities of the Leuven region with responsibility for development planning and public works. Leuven municipalities and Interleuven are dependent on Eandis (an independent company majority owned by municipalities) that is responsible for maintaining and repairing street lights, lighting infrastructure and power distribution.

  - *The Interleuven BLISS investments considered the aspirations and wishes of citizens and the social and environmental benefits of innovative lighting solutions. The technical design and evaluation together with the consumer evaluation was carried out by Interleuven, Infrax and Eandis staff.*

- **Eindhoven** is an autonomous municipality with elected politicians responsible for public lighting. It has a staff of 8 lighting professionals who design and manage lighting installations within the municipality extents. External contractors undertake the installation and maintenance of street lighting on behalf of the municipality. All expenditure associated with public lighting including capital, revenue and energy costs are funded directly from Eindhoven's municipality budget but within the test area Strijp-S these costs are shared with the site owners.

  - *The Eindhoven BLISS investments were made in the Strijp-S regeneration and demonstration area which is jointly owned by the municipality and a private development company. The focus being to provide new innovative lighting infrastructure, designs and solutions and in so doing to challenge conventional ways of thinking, functionality, specifications and standards in public lighting. The technical design and evaluation together with the consumer research was carried out by specialist consultants.*

Torenallee Strijp-S, Eindhoven

- **Kaiserslautern** is an autonomous municipality with an elected politician responsible for public lighting. The communal local energy supplier is appointed for technical design and implementation.
  All expenditure associated with public lighting including capital, revenue and energy costs are funded from the budgets of Kaiserslautern and their energy supply company.

  - *The Kaiserslautern BLISS investments considered the aspirations and wishes of citizens and the social and environmental benefits of energy efficient and innovative lighting solution within the municipalities town centre. The main objective was to achieve a reduction of anti-social behaviour, whilst reducing carbon emissions and energy cost. The technical design, evaluation and consumer research was carried out by the city department for urban development.*

City Centre coloured lighting schemes Kaiserslautern (TCS 9.1)

2.3 Funding Models

It is important to note that funding models used by and available to municipalities in Europe for new and replacement lighting infrastructure vary. The partners all use variations on the traditional model for public lighting where the infrastructure is generally owned by the municipality or a public agency, whilst the power supply can be in part privately owned. None of the partners use Public-Private Partnerships or have transferred the management of their public lighting asset to a private company.

In Germany there are no national regulations or strategy for street illumination or related funding and management. Municipalities develop their own funding solutions guided by engagement with businesses, citizens and politicians. New lighting schemes are funded from municipality borrowing and from income. Maintenance is funded from income. Funding may also be available from the state government.

In Belgium the lighting for new developments is financed by the public or private developers with the municipality responsible for maintenance with the assistance of the DNO's – who also assists with advice on energy efficient approaches and techniques. The funding of municipalities are financed by municipality borrowing and from a system of taxes. There is no direct public lighting tax.

Private funders of lighting for new developments generally wish to reduce capital expenditure and rarely consider ongoing energy maintenance costs because the municipalities will pay eventually for the cost of energy and indirectly for future maintenance. It is acknowledged that municipalitiesshould have additional input (with the initial investor) with regard to the design selection criteria and equipment specification. The BLISS project has assisted the Interleuven municipalities in developing policy and adding additional emphasis to developing a Total Value of Ownership approach.

In the United Kingdom new lighting schemes are funded by the Highway Authority (generally the municipality for the area in question).
Major lighting schemes on national roads are funded by Central Government. Lighting schemes on new private developments must meet the design standards of the Highway Authority and are funded by the developer. The Highway Authority takes on responsibility for their maintenance and management on completion of the scheme.

In the Netherlands new lighting schemes are funded by the developer either the municipality or the private investor. 'Above ground' infrastructure is maintained by the municipality where it is public land or roads, but can be the responsibility of private landowners on private land. With some grey area maintenance responsibilities and costs are agreed through contracts. "Below ground" power infrastructure is traditionally owned by the electricity companies. With the emergence of LED, intelligent networks and 'smart' control systems funding and roles and responsibilities are being reviewed and re-cast.

3. Lighting Design Criteria

3.1 The Need for Public Lighting

The need to reduce carbon emissions coupled with the global economic downturn and rising electricity costs has driven municipalities to review their policy on the provision, operation and maintenance of public lighting.
The benefits of appropriate, efficient, well maintained lighting include:

- assisting in prevention of darkness traffic accidents;
  enabling a safe route of passage
- discouraging street crime and antisocial behaviour;
  enabling a safe route of passage
- promoting sustainable transport;
  enabling safe access to public transport, cycling and walking
- promoting physical fitness;
  walking, jogging and cycling
- facilitating social inclusion;
  safe and easier access to local amenities
- promoting economic development;
  extending operating hours and improving the appearance of commercial centres, local business and attractions
- encouraging life-long learning;
  after dark access to educational facilities
- assisting the emergency services to undertake their duties after dark
- promoting cultural identity;
  illumination of land marks and points of interest.

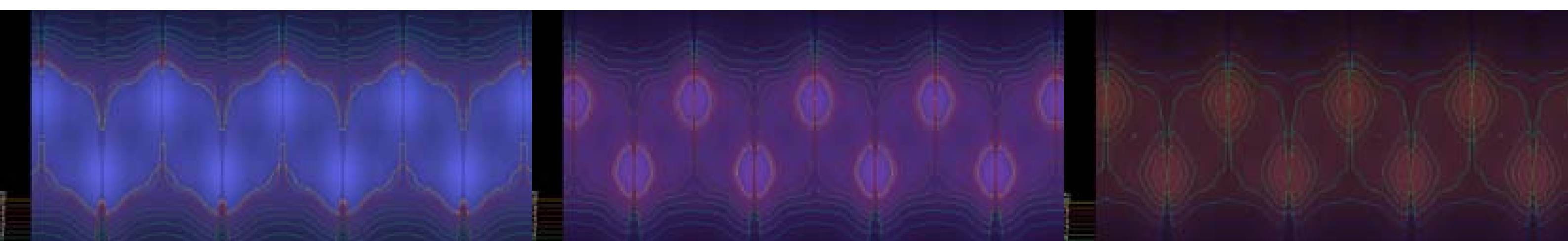
College Water street, St. Helens

Many towns and cities have entertainment, culture and business activities that are "24/7" (all day & all week) Good quality, effective and interesting public lighting plays an important role in adding to the ambience, adding further to citizens enjoyment of their commercial centres whilst also offering them a safe route of passage to and from their destination.

3.2 Good Design Practice

Design practice has evolved rapidly in recent years with new thinking in public lighting and the availability of new and emerging innovative technology. There are many and diverse tools available to a municipality to reduce carbon based energy consumption: from simply considering the removal of light points, to retrofitting energy efficient light sources and compliant control gear to implementing sophisticated Adaptive Intelligent Lighting (AIL) control systems that provide the required lighting level appropriate for the situation.

Visualized light intensity calculations, part of design proces Eindhoven (TECEO-S). (TCS 6.1)



3.2.1 The Design Process

Municipalities should establish a lighting policy, which includes the considerations of all identified stakeholders. This policy should be reviewed at regular intervals as changes in legislation, guidance, local circumstances as technological advancement dictate. This could be considered by a select panel representing stakeholders including community representatives. Policy should be reviewed periodically as legislation and technology changes occur.

Where applicable, a detailed assessment of the asset condition should be undertaken to determine its age, condition and energy profile. This will assist in assessing if the existing power infrastructure and lighting columns can be re- used during the design development phase of the lighting design selection process and will assist in determining the most cost effective approach to be applied. The following steps form part of this process.

New luminaires installed on existing columns at Nieuwland. Interleuven (TCS 8.3)

Figure 1.1 BLISS Design Process

1
Design development
Create a lighting usage profile detailing task requirements, issues and risks associated with the locations at different times of the night

2
Lighting classification selection
Select the appropriate lighting classification using international, national and local design standards

3
Risk assessment
Develop a risk assessment considering primary and secondary considerations; Traffic, user group, surrounding environment, ambient luminance

4
Communication plan
Develop a communication plan and engage with stakeholders, as required

5
Stakeholder consultation
If necessary, the initial lighting classification should be adjusted up or down based on the risks assessment and stakeholder consultation

6
Control method
Establish any additional savings by varying the light output or switch off, based on a predetermined strategy (legislation, local circumstance and industry best practice)

7
Innovation register
Evaluate existing, new and emerging equipment based upon functionality, interoperability, scalability, lifetime cost, maintainability and sustainability

8
TCO/TVO
Undertake a Total Cost / Value of Ownership based on local constraints, drivers, forward strategy, budget and equipement specifications

3.2.2 Design Considerations

The transnational exchange by partners of their practices has allowed the BLISS project to develop a framework of the relevant design standards, regulations and criteria that should be taken into account for investments. The framework is outlined in this chapter and the way in which it has been used to frame the consultation with stakeholders is described in chapter 5. This framework combines both objective (O) and subjective (S) criteria and has been termed the 'design considerations'. These are set out in table 3.1. Similar and related criteria were developed and used to frame the evaluation and report the results of the investments.

Nieuwland, new scheme. (Interleuven). (TCS 8.3)

Table 3.1 Design Considerations

Criteria	Example	Characteristics	O/S
Road type	Subsidiary road/ strategic route/ distributor road/ car park	EN 13201 Table A describing the classification of the road, highway or area to be lit.	O
Traffic flow	Low/ medium/ high, Light/medium/heavy	Average Daily Traffic flow, road speed limit, on or off road parking, traffic calming or signage, public transport use, unusual flow characteristics	O
Crime rate	Low/ medium/ high	Incidence of crime directly or indirectly related to illumination levels: burglaries, vehicle and bike theft and theft from a vehicle, criminal damage, rowdy and inappropriate behaviour, drug offenses, sexual offences and arson; dumping and graffiti. Presence or absence of CCTV surveillance equipment.	O
Accidents	Number of incidents recorded	Accident statistics - reported accidents: fatalities, bodily harm or material damage.	O
Social Demographic considerations	Age & gender charts, IMD deprivation score	Data on characteristics of local populations by Gender and age: 0-15, 16-29, 30-44, 45-64, 65+ Deprivation: UK Index of Multiple Deprivation (IMD) score ranked out of 10 for each LSOA (Lower Super Output Area) in the UK. IMD score 2010 score combines 7 domains of deprivation: Income, employment, health and disability, education and training, barriers to housing and services, living environment and crime.	O
Colour rendition	Ra $\geq$ 20 - 60	Colour Rendering Index (CRI) is the measure of the ability of a light source to render colours of objects correctly (Ra 60= daylight). Ra $\geq$ 60 is appropriate for facial recognition	O
Environmental zone	E0/ E1/ E2/ E3/ E4	E0: Protected; Dark; UNESCO Starlight reserves, IDA dark sky parks E1: Natural; Intrinsically dark; National parks, areas of outstanding natural beauty E2: Rural; Low district brightness; Village or relatively dark outer suburban locations E3: Suburban; Medium district brightness; Small town centres or suburban locations E4: Urban; High district brightness; Town/city centres with high levels of night-time activity	O
Safe ease of passage	Good/ moderate/ average/ poor	Footpath surface quality / Pedestrian ease of passage / Adjacent traffic speed zone (slow/medium fast). / Footpath/road separation / Accessibility of public transport / General visibility / On/ off road parking	S
Design uniformity	0.25/ Uo high as possible/ class specific	Required overall uniformity of illuminance (Uo) in accordance to the EN lighting classification (cd/m2)	O
Control method	CMS/ PIR/ lumen level reduced to / switch off	Details of any control method applied to the scheme; None Dimming with % lumen level reduced and hours PIR/Sensor Remote control system (Zigbee/Wifi/optical)	O
Electricity supply	Distribution Network Operator/ Private Network Cable	Power supply including voltage	O
Pre works survey		% of the residents felt safe walking alone during the night % felt that the old installation was 'comfortable on the eye' % stated the old installation shows up the whole street well % can see people at a distance clearly % has no problem to see obstacles on the ground % of the residents stated that the old lighting installation was too dark % says that the old installation doesn't show the colours properly	S

Table 3.2 Table of evaluation and results

	Example of before	Example of after	Example outcome
Calculated energy saving	11,821 kWh 6,147 Kgs of CO_2	6,283 kWh 3,267 Kgs of CO_2	47% energy saving
Number of luminaires	36no.; 30no. 55W LPS 6no. 70W HPS	38no.; 34no. LED 4no. Cosmopolis	Increased units
Calculated colour rendition	Ra ≤ 20	Ra 65 – 75	Improved colour rendition
Calculated colour temperature	1800K – 2000K Warm white	2850K– 5700K Warm white – Cool white	Improved appearance
Control regime	None	50% 22:00 – 06:00	Improved functionality
Measured lighting levels	Horizontal illuminance E in lx: 4.02/ E_{min} in lx: 0.56	Horizontal illuminance E in lx: 6.51/ E_{min} in lx: 2.95	Improved lighting level
Public consultation research	• 44% felt safe alone at night • 58% poor visibility/ colour rendition • 58% 'comfortable on the eye' • 55% illuminated their properties	• 91% felt safe alone at night • 8% poor visibility/ colour rendition • 82% 'comfortable on the eye' • 81% illuminates their properties	Improved perception
Measured crime	Medium	Low	Reduced crime
Measured accidents	1	0	Reduced accidents
Measured luminaire faults	21	4	Reduced faults

3.2.3 *The Approach Framework*

Partners identified that there are many possible approaches (or options) to assess existing, new and emerging energy efficient equipment to reduce energy consumption. Each of these approaches has been explored by the partners in the TCS and investments. Choosing the most appropriate approach requires a bespoke Total Cost / Value of Ownership evaluation. The approaches identified by BLISS include: those listed in figure 3.2.

Figure 3.2 BLISS Approaches

1 > No Action
- Do nothing

2a > Lamp
- Install a replacement equivalent energy efficient light source

2b > Lamp & trimming
- Trimming & retrofit energy effcient light source/control gear combination

2c > Lamp & variable adaptive lighting
- Retrofit energy efficient light source/'standalone' variable adaptive lighting

2d > Lamp & part night switch off
- Retrofit energy efficient light source/'standalone' part night switch off adaptive lighting

3 > Luminaire
- Install energy efficient 'standalone' intelligent luminaires

4a > Motion detection
- Install a 'networked' motion detection system (Passive Infrared)

4b > Central Management System
- Install a 'networked' variable adaptive lighting (Central Management System)

4c > SMART City
- Install a 'networked' SMART City connected variable adaptive lighting (Central Management System) with SMART City connect

5 > Renewable energy
- Consider the use of alternative Renewable power sources (direct or off-set)

6 > Switch off
- Consider full switch off/ road lighting removal (following appraisal period)

7 > Retro-reflective traffic signage
- Deillumination/retro-reflective replacement of traffic signage equipment where permitted

8 > Decorative lighting
- Deployment of City decorative lighting - Subject to sequential test

Snapshots of the BLISS projects.

Trimming; (2b) refers to varying the time that lighting switches on and off through conventional switching methods including the replacement of existing Photo Electric Control Units with fully electronic low energy alternatives.

Variable Lighting; (2c) also called adaptive lighting or profiling is an option to increase or decrease the lighting level dependant on local conditions.
Industry good practice dictates that the lighting intensity is changed in line with traffic volume or pedestrian flow. The change in lighting level should reflect the lighting in the next appropriate lighting class whilst maintaining the most onerous uniformity condition.

Switch off (Part Night or Permanent); whilst the need for lighting in our towns and cities is understandable and accepted, public lighting may not be required in rural locations.

In order to avoid unnecessary future costs, municipalities need a public lighting strategy which only permits lighting installations where there is a positive benefit to the community as a whole. It is important to remember that the main purpose of road lighting is primarily for the safety and well-being of the local community and road users. Other efficiency saving approaches and techniques should be considered before switching off public lighting in the majority of situations.

Approaches 2d and 6 consider either part night or permanent switch off.
In some circumstances it may be argued that switching road lighting off through periods of low usage or total removal may be prudent thinking. However it still remains a very emotive topic. Lighting professionals need clear and accurate data to make informed decisions following a structured approach including stakeholder engagement, safety benefit risk analysis and cost benefit evaluation.

3.3 Total Cost of Ownership

Public lighting has an important role to play in today's 24 / 7 society.
However, public lighting also needs to be correctly maintained to ensure safety requirements are met. Public lighting also consumes energy, working against the global long-term strategy to reduce greenhouse gas emissions. Through careful consideration, we have ultimately been able to close the paradox between the requirement for energy reduction and the desire for improved lighting.
TCO offers municipalities a tool to understand the capital and operating costs of a (potential) lighting system to:

- evaluate and compare alternative lighting designs and approaches
- plan implementation
- confirm cost estimates and set budgets
- validate procurement

The evaluation of many large road construction projects often uses the Life Cycle Costs method (LCC). It is important to include the whole life cycle costs in the evaluation of any public lighting proposal [9]. Considerable costs are incurred during the operational period of the installed equipment resulting from energy consumption and maintenance operations and these should be considered. BLISS partners have confirmed that selecting some energy efficient approaches available may increase the initial investment capital costs; however this can result in lower energy and maintenance costs leading to lower life cycle costs.

As part of their TCO's BLISS partners have each;

- Produced an outline scheme design to provide sufficient detail to enable costs to be estimated.
- Evaluated the potential equipment to confirm 'fit for purpose' including availability, functionality, maintainability, life time cost, robustness, interoperability, scalability and sustainable qualities.
- Assumed public lighting maintenance will be combined with other highway related maintenance activities.
- Estimated the cost of dealing with equipment faults based on historical data, manufacturer's data and industry best practice forums.
- Excluded the costs associated with emergency responses.
- Calculated initial energy cost using the currently applicable rates negotiated with the appropriate energy supplier.
- Considered possible future equipment price and operating cost increases and the impact of inflation.

Various national and international guidance is available to aid municipalities, including ANNEX A of CIE 115: 2010 - Lighting of Roads for Motor and Pedestrian Traffic, which includes worked examples of economic calculations. Municipalities may choose to adopt a simplified process to formulating a TCO methodology. Following a series of partner knowledge share activities it became apparent that there were significant differences in initial capital procurement costs for both labour activities and material procurement across the partnership. The subsequent cost management of Partners public lighting term maintenance contracts differed again in terms of labour and material costs which was dependant on the length and nature of the contracts.

Across Europe there is no standard pricing framework for electricity charged to municipalities. The price being paid being dependant on the agreement type, its commencement date and duration, the type and nature of any additional charges, the percentage of "renewable" energy purchased and the 'buying power' of the individual municipality or centralised buying group.

What emerged during the project was the different calculation methods applied and the responsibilities associated with preparing and approving the TCO justifications. BLISS partners consider that there would be benefits if there was an agreed TCO standard for lighting.

9 http://ec.europa.eu/environment/gpp/pdf/toolkit/module1_factsheet_lcc.pdf

Philitelaan Strijp-S, Eindhoven

The Technical Case Studies describe the way in which the Partners calculated TCO. A summary of the factors included by each municipality is shown below;

	Interleuven	St. Helens	Eindhoven	Kaiserslautern
Responsibility for preparation of TCO	Eandis	St. Helens	Eindhoven	Kaiserslautern
What is included in TCO calculation : 1.Capital	Site clearance of existing installation Supply and installation of the equipment (luminaire, lamp, column and control), depreciation not capitalised, Underground power supply owned by Eandis/ Infrax as Distribution Network Operator – capex costs included	Site clearance costs of the existing installation Supply and installation of the equipment (luminaire, lamp, column and control) Electrical works (Distribution Network Operator, and / or Private Network Cable)	Site clearance of existing installation Supply and installation of the equipment (luminaire, lamp, column and control), depreciation not cappitalised,underground power supply owned by private network Distribution Network Operator – capex costs included	Site clearance of existing installation Supply and installation of the equipment (luminaire, lamp, column and control), depreciation not capitalised,underground power supply partly owned by private network Distribution Network Operator – capex costs included
2.Energy	Based on Estimated Actual Consumption provided by manufacturers but validated by Eandis tests; Cost per kWh Burning hours Dimmed hours	Based on Estimated Annual Energy Consumption at commission year, excluding inflation and taxation; based on independently tested data Energy cost per kWh, regime, burning hours per year, carbon (0.52 Kgs per kWh)	Based on real metered costs	Based on real metered / calculated costs
3 Maintenance	Lamp replacement, luminaire cleaning and structural inspection, electrical testing and inspection regimes. – four year cyclical programme for HPS/CPO and LED	Planned maintenance regimes; lamp replacements, luminaire cleaning, structural inspections and electrical testing. 4 year cyclic activities HPS and CPO. Only cleaning, structural inspection and electrical testing for LEDs. No additional LED module replacement cost included	Lamp replacement, luminaire cleaning and structural inspection, electrical testing and inspection regimes. – four year cyclical programme for HPS/CPO and LED	Lamp replacement, luminaire cleaning and structural inspection, electrical testing and inspection regimes
TCO duration	25 years	25 years	20 years (luminaires) 30 years (poles)	20 years (luminaires) 30 years (poles)

3.4 Total Value of Ownership

Custom designed luminaire for the BLISS Strijp-S project: with RF Stepless Dim Controller - 61% energy saving (TCS 6.2)

The Total Value of Ownership is not a new concept. It is derived from Total Cost of Ownership but includes benefits which are sometimes difficult to quantify but which are 'of benefit' to the overall value of the project.

Since the inception of the BLISS project the partner cities recognised the speed at which progress was being made toward Solid State Lighting (SSL) and Adaptive Intelligent Lighting (AIL) technology. In this context public lighting infrastructure will become a dynamic platform though a connected system. With appropriate lighting infrastructure, continuous innovation will be possible in public lighting installations.

The partners recognised that the conventional TCO is an incomplete evaluation model, when considering a possible Smart City deployment protocol, presenting an opportunity to develop an alternative Total Value of Ownership (TVO) business case. It was recognised that there are however significant capital costs associated with installing the necessary communication network capability to realise the innovation and value from AIL. (See image page 36).

In the context of the BLISS project significant 'fibre optic' based infrastructure investment was made at Strip-S, St Helens have opted for a wireless communications approach whilst Interleuven examined the potential of utilising the power distribution network system to communicate between lighting positions. Kaiserslautern used SSL linked AIL which was triggered by movement to deter low level crime and reverse the decline of part of the city centre.

What has emerged from detailed consideration of TVO by the partners is that a move from TCO to TVO requires a municipality to establish a strategic plan for public lighting which is;

1. Integrated with the city's vision in terms of liveability, economic growth, well-being and sustainability.
2. Includes a connected public lighting infrastructure that is designed to be a "network of networks" and a platform for service innovation.
3. Managed using open source platforms and applications utilising the latest technologies
4. Funded using a revolving model where operational cost savings (not only from public lighting) are reinvested in the platform to enable new functionalities.
5. Measure the total value generated year-over-year in terms of savings and revenues, jobs created, enhanced asset values, and liveability (soft values) improvements.
6. Shared between municipalities and their communications partners, recognising that public lighting will become part of a network of services.

At the start of the BLISS project the installation of Adaptive Intelligent Lighting systems interfacing with a municipality's wider network was an aspiration of the partners whilst LED was widely untried and untested.

The transition towards Adaptive Intelligent Lighting (AIL) requires a commitment to significant 'up front' additional investment in lighting infrastructure beyond the standard required for more conventional methods. TCO cannot accommodate the additionally of this infrastructure investment nor the added value that arises from the almost infinite variety of lighting designs that can be configured.

TVO acknowledges and values these soft benefits, and recognises the ability of AIL to influence business profitability and economic value of public places and spaces. However in the difficult financial situation that most municipalities find themselves in at present there is intense pressure on budgets and on reducing the capital and operating costs of public lighting.

There is therefore a tension between the aspirations and potential of AIL and the realities of reducing costs of public lighting. For those municipalities seeking to justify investments in SSL and AIL then TVO offers an appropriate model capable to demonstrating the wider benefits, justifying 'invest to save' borrowing.

The BLISS partners' vision and recommendation is that there should be a move from TCO towards TVO where the scenario dictates that an enhanced lighting experience would be beneficial and this

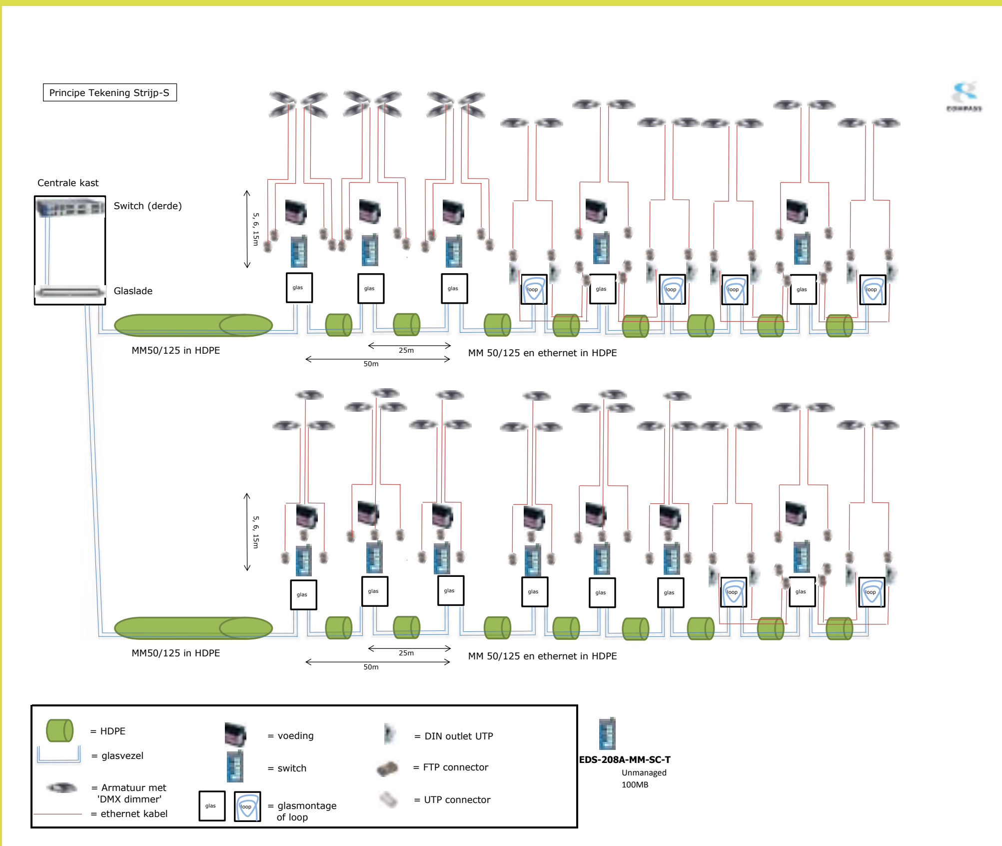


Diagram of the Strijp-S 'backbone' infrastructure. (TCS 6.1)

should be used to assemble the business case for SSL and AIL as an essential component of Smart cities.
The additional benefits that good quality intelligent lighting adds to each situation need to be considered in greater detail to capture the increased performance advantages gained which create enhanced value to the local community and wider stakeholders, whilst quantifying any additional revenues that this may bring. Within a Smart City context, infrastructure will become a dynamic platform enabling continuous innovation; therefore it needs to be looked at from a different point of view, only then does the case in favour of sustainable, liveable infrastructure become clear.

It is only towards the conclusion of the project and with the innovation and ambition of the partners that it was possible to identify some of the benefits and issues associated with TVO. The partners believe that additional impact assessments need to be undertaken, considering the following elements, when moving from TCO to TVO. Some of these are listed below;

New LED as part of central St. Helens regeneration scheme - 24% energy saving. (TCS 4.2)

Emergency situations
Functional and decorative lighting can be combined to provide better visibility and dynamic routing for directing emergency services to a specific location. A common aim should be that functional, decorative and even commercial lighting is smartly connected in a way that together they meet the set norms and standards in order to create a most efficient total lighting scheme. *TVO will identify added value of being able to respond to emergency situations – valuing lifesaving and injury in particular.*

Crime
Lighting can dynamically respond to the presence and noise of citizens and vehicles: increasing in intensity, making the surrounding areas feel more secure, adding to journey ambience, social surveillance and the capture of CCTV imagery; *increasing the value of properties arising from reduced fear of crime whilst reducing the need for emergency service intervention.*
TCS 4.2, 8.6.

Accidents
Quality lighting will assist road users to identify obstructions and possible conflicts assisting *in reducing the cost and number of accident reducing causality reduction targets, insurance claims and the attendance of emergency services. TCS 3.14.*

Weather Conditions
Lighting can automatically adapt to local patterns, luminaries being activated when there are high levels of cloud, fog or storm conditions for example. TCS 6.6.

Economic value
Property owners can control the lighting in front of their establishments to interact with their visitors. Light could brighten as someone approaches a school, shop, factory, plaza, college or monument - creating an inviting

atmosphere; *TVO will identify added value to shop/properties in terms of increased turnover and profitability. TCS 4.2, 6.6.*

Landscape, Townscape, Heritage

Creative, adaptive lighting can be thought provoking and dramatic and change the feeling of a public space. Quality lighting assist in enhancing the assists municipality's identity and appeal, encouraging tourism and economic growth through lighting festivals linked to events. *TVO will identify and value environmental and cultural and identity aspects. TCS 6.7.*

Real time data

Central management systems with SSL / AIL can allow hours of lighting and levels to be flexibly adapted and the costs and benefits to be accurately calculated. This can also be carried out in parallel with awareness and education campaigns with citizens so that they can understand the relative costs of different lighting designs and the 'state' of lighting during incidents. *TVO will allow actual costs of accidents, crime, and energy to be calculated.*

Connectivity

The lighting infrastructure can be used as part of a municipality wide intelligent network collecting and disseminating data on traffic, parking, waste management, air pollution, fine dust levels, ozone levels, noise pollution, and people and traffic flows etc. It can be part of a citywide intelligent communications network used by the private and public sector. *TVO will allow the extent to which lighting is only one user of the network to be valued and costed. TCS 6.1.*

Energy

Municipality wide energy consumption and emissions can be managed as all functional and decorative urban lighting. Selected commercial and private lighting and light art can be controlled simultaneously though a AIL system. *TVO will allow the energy saving benefits of city wide inter-connected Smart Central Management System to be valued.*

Health and well-being

Walking, cycling and use of open space can be encouraged, increasing the health and well-being of the community. *TCO will identify all the improvements to health and wellbeing of residents to be valued. TCS 5.4, 8.6.*

City Centre coloured lighting schemes Kaiserslautern. (TCS 9.1)

Introducing lighting into a heritage park brings economic and social value but uses energy, Victoria Park, St. Helens. (TCS 5.4)

3.5 Transnational Learning

Partner's drivers and constraints were identified at an early stage through a series of cross boundary evaluation exercises and throughout the period of the BLISS project the design selection criteria requirements of Partners have been examined. Sixteen workshops and knowledge share exercises were arranged to discuss a range of topics including crime, accident and socio economic data sources, their relevance and subsequent application with the public lighting design process.

As each investment had different characteristics, design drivers and expectations, the design approach and equipment specification varied and the selection process formed an intrinsic part of the joint evaluation process undertaken.

Taken together with the varying appetites for innovation this has allowed the partners to fully test the acceptability and energy efficiency of a diverse range of lighting solutions.
By identifying their cultural, social and political differences, the Partners have developed an understanding of their differing needs. Working together, the Partners have been able to assist each other and have been better able to provide working solutions.

Examples

Issue:
The importance of reducing the fear of crime and social acceptance of CCTV in the UK requires a high standard of public lighting.
Solution:
High standard of public lighting required, preferably with white lighting and controls.
Lessons Learned:
Eindhoven had previously used LED lighting, including motion detection. This gave St.Helens confidence to trial this type of lighting with controls.

Issue:
The shared ownership of lighting in Belgium and, in particular, the financial treatment of depreciation/cost "overruns" had reduced the appetite for innovative designs and specifications, where operating costs are less certain.
Solution:
More efficient public lighting schemes incorporating "white" light including LEDs.
Lessons Learned:
By inviting the Belgian Electricity Network Operator to Steering Group Meetings, presentations were given which highlighted the success of LED lighting. This gave an impetus to LED lighting trials in Interleuven and Belgium.

Issue:
In Dutch municipalities there is a cultural and political acceptance of their role in working with academies, manufacturers and designers, to provide opportunities to test and pilot new technological lighting solutions – sometimes without fully understanding how they complement existing infrastructure and systems.
Solution:
Presentations of projects at Steering Group Meetings and Seminars to a wide range of stakeholders, including politicians, senior lighting professionals, has demonstrated the virtue of embracing new and emerging technology and trialling innovative schemes to deliver new concepts in lighting.
Lessons Learned:
It is important to pursue technological innovation but at the same time, involve and inform relevant stakeholders to ensure that they are aware of the direction that the project is taking.

3.5.1 Energy Savings

The aim of the BLISS project was to examine ways to reduce the amount of energy consumed by public lighting using a varied approaches and the application of energy saving products across a range of scenarios.

Each of the partners is obliged through EU, national and local regulations and policies to achieve reductions in their energy consumption. For example St. Helens Council produced a "Carbon Reduction Policy" document in 2008 to ensure that the Council would achieve the national carbon reduction target of a 20% reduction on CO2 emissions by 2020. Public lighting was identified as consuming almost 30% of total energy consumption by the municipality and it has been a key target for energy reduction.

The energy reduction targets for St. Helens include legally binding national targets that have been translated into the contribution that the municipality needs to make. This legally binding target is a key driver for St. Helens and means that the value of carbon reduction is a key political driver and the reduction of energy is a careful consideration for all new and replacement public lighting schemes.

The energy reductions required to be made by Belgian municipalities are set in statute. However the BLISS project has illustrated how energy efficiency was not always considered, particularly by local politicians to be the primary design driver when new / replacement works were being proposed

In Belgium the energy for lighting is administered by independent agencies (Infrax and Eandis). This means that the extent to which energy efficiency is used as a design driver depends not only on municipality policies and practice but also on those of these two agencies. The visual appearance, technical performance and stakeholder acceptability of lighting schemes tends to be given equal weight to energy reduction by the local decision makers. BLISS has confirmed that the extent to which energy saving is a design driver is entirely dependent on the importance that it is given by politicians.

Energy provision and the expected annual savings have been calculated for individual investments based on Partners' individual values and examples of these are included within the individual Technical Case Studies and the Final Report.

BLISS has confirmed that the metrics used by partners to calculate the amount of energy used varies depending on how the energy is generated / distributed and policies on load profiling and purchasing. In the UK, metered supplies are still relatively uncommon within public lighting installations and an Estimated Annual Consumption (EAC) approach is common. Most partners use metering systems to record energy consumption.

Greenhouse Gas conversion factors and p/kWh charges vary considerably based on local circumstances and details are described in the final BLISS reports.

3.5.2 *The Appearance of Public Lighting Columns and Lanterns*

The appearance of public lighting columns and lanterns can add (or detract) to the street scene. In heritage areas, such as parks or town centres, there is often a desire to install lighting which matches the characteristics of the area. This can often result in lighting being installed which is not the most efficient but which satisfies the need for it to harmonise with its surroundings.

Examples

Issue:
In Interleuven, a lighting scheme was needed to replace existing obsolete lighting units in a Town Centre. The existing lighting units comprised "white" discharge lighting.
Solution:
A "white" discharge lighting scheme was chosen which was cheaper to purchase and install than an LED solution. The operation and maintenance costs of the white scheme higher than for an LED scheme, but it harmonised with the lighting in adjacent areas. The LED scheme would have appeared 'harsh and cold' in the Town Centre.
Lessons Learned:
It is important to consider the characteristics of an area and the impact that would be caused by a new lighting scheme. It is sometimes worthwhile paying a little more for running costs to achieve a more environmentally acceptable scheme.
In this instance, savings were achieved by installing a new discharge "white" lighting scheme but the savings were not as much as would have been saved if an LED solution had been adopted.

Issue:
Lighting to be installed as part of the restoration of a Historic Park – to be financed from external sources (Heritage Lottery).(TCS 5.4).
Solution:
Although the park was being carefully preserved to retain its historical character, consultation with stakeholders (the Friends of the Park) identified that modern LED lighting was preferred to traditional "heritage" style lighting.
Lessons Learned:
It is important to consult with stakeholders to ensure that the final option chosen meets their requirements.

3.5.3 Wildlife

Responsibility for looking after the interests of wildlife in lighting schemes is often not a material consideration of municipal lighting designers.
St. Helens wanted to install lighting on a car park at a popular country park visitor centre (TCS 5.1). Similarly Interleuven wanted to replace lighting in an existing leisure park at Stadspark Aarschot.(TCS 8.6) Both had the objectives of reducing energy consumption, minimising light pollution and reducing the impact on bats. A Partner meeting held in the UK specifically brought together ecology and observer specialists to consider these impacts and recommend mitigation measures. Concern to reduce impacts on bats led to innovations in using motion detection to provide on demand light and LED luminaries which provided instant illumination with minimum light pollution. At Stadspark Aarschot where the usage of the park and the fear of crime did not lend itself to a motion detection system LED luminaries with a 50% dimming routine between the 10 pm and 6 am was introduced.

New LED lighting scheme at city park Aarschot. (Interleuven) (TCS 8.6)

Schreder Aramis 60 W Cosmopolis lamp (TCS 7.2)

3.5.4 The gradual evolution of SSL

At the outset of the project the performance and reliability of LED public lighting luminaires was being questioned by many professional lighting engineers. As a consequence the design development process for some investments early in the project selected the safer and known energy efficiency, maintenance and cost characteristics of various High Intensity Discharge (HID) light sources. (TCS 7.2, 7.11 and 7.6). As the project has evolved more convincing evidence of LED reliability has become available, through a series of partner collaboration and knowledge share activities and their costs have fallen as performance and reliability has increased as 2nd generation components enter the marketplace. This together with development of electronic controls allowing the adaptive variable control of LEDs has meant that similar investments undertaken towards the end of the project have considered LED as a viable alternative to more conventional light sources. Those investments where this is relevant include. (TCS 8.4)

New installation on distributor road at Kortenaken (TCS 7.11)

Two images; Previous and new scheme / luminaires at Tiensestraat Leuven (TCS 7.6)

3.5.5 *Future proofing and control*

The desire from key stakeholders for an innovative approach to lighting control within Strijp-S led to the recognition that there was a pre-requisite for investment in control infrastructure and 'cutting edge' luminaries.

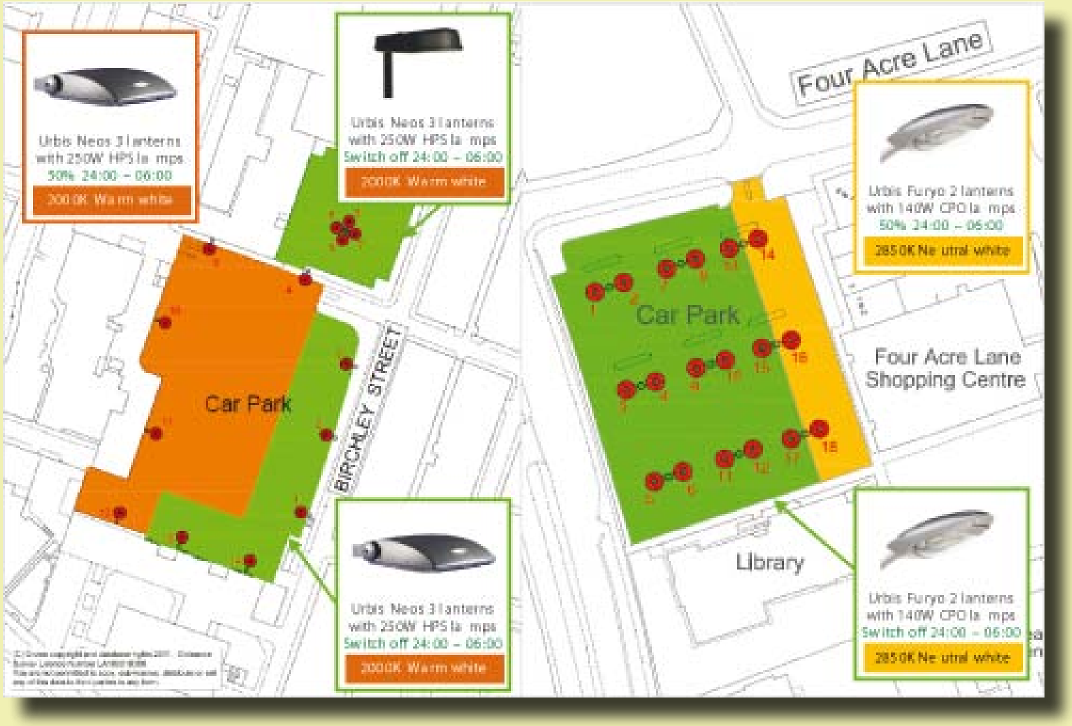
The fact that Strijp-S is being redeveloped and the entire site infrastructure was being replaced meant that the 'backbone' (TCS 6.1) would be both physically possible and a cost effective investment. This new infrastructure has allowed a diversity of innovative LED based lighting installations to be made, allowing almost infinite degrees of control over luminaire colour rendition, temperature, levels of illumination, and timing. The designs have been driven by a commitment to broad sustainability criteria and citizen well-being. (TCS 6.7)

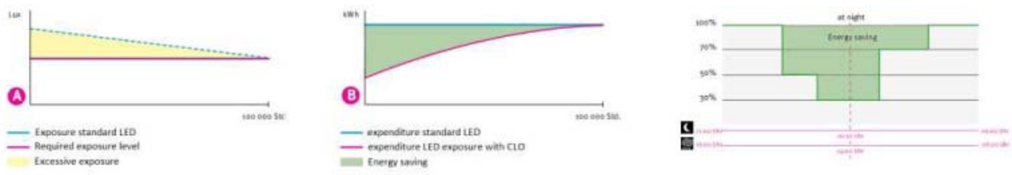
The evaluation of the stakeholder acceptance, total economic value, and energy savings has started with the BLISS project but will continue as Strijp-S makes further LED investments and continues to be at the forefront of lighting innovation - with the benefit of the 'backbone'. With the recent release of electronic controls for LED dimming and the learning from similar adaptive intelligent lighting controls being installed by St. Helens, Eandis and Infrax decided to change their design evaluation process standard so that all new LED investments are equipped with electronic controls (TCS 8.4).

Installation of new LED luminaires - 38% energy savings at Wakkerzeelsebaan, Leuven. (TCS 6.1)

These dimming controls will only be able to be used however as municipalities invest in new high voltage infrastructure power and control systems.
The potential for energy savings to be achieved through Central Management Systems (CMS) was explored by St. Helens (TCS; 5.2, 5.3). This has confirmed that investment in the necessary control infrastructure can lead to significant energy savings (66%), merely by replacing the 400W HPS lamps with 250W HPS lamps and 250W HPS lamps with 140W CPO.

New LED lighting controlled through CMS – 66% energy saving. St. Helens. (TCS 5.2 5.3)





Second generation LED luminaires with almost infinite coulor and control options - 78% energy saving. (TCS 6.3)

3.5.6 Coloured lighting

The development of LED and digital communication protocols has brought the possibility of introducing colour into public lighting. The BLISS project has tested the stakeholder acceptability of colour in public lighting situations. It has also sought to understand and test equipment, standards and the contribution it can make to improving health and well-being and in marketing a city and its attractions. Eindhoven, St. Helens and Kaiserslautern have each made investments in colour lighting. (TCS 1.1/1.2/1.3/9.1/6.4). Each of these investments has demonstrated that colour lighting can change users' perception and use of places and spaces.

Coloured lighting installed on a new bridge as a new attraction and to promote the route St. Helens. (TCS 1.1)

With a significant antisocial behaviour problem in part of its city centre, Kaiserslautern introduced an innovative multicolour lighting system. Allied to an in depth engagement with residents the scheme is widely accepted as it has dramatically reduced the antisocial behaviour and graffiti. It is important to note that the quality of life, the physical environment and residents' satisfaction has all improved. But because coloured lighting is less energy efficient than white lighting, the politicians of Kaiserslautern, St. Helens and Eindhoven all chose to accept higher energy consumption (and costs) as a worthwhile investment for the benefits that have followed. With no EU standards or norms for coloured public lighting the BLISS partners have developed, through their meetings and exchanges, a framework for the design of coloured public lighting – Streets and urban spaces (TCS 6.4), Bridges and structures (TCS 1.1/1.2/1.3) and city centre (TCS 9.1).

It has not been possible to assess the benefits of coloured lighting for the health and well-being of residents. Such a study is beyond the scope of the BLISS project. However it is important to recognise both the significance of these benefits and the difficulties of attributing a financial value to them.

City Centre coloured lighting schemes
Kaiserslautern (TCS 9.1)

3.5.7 *Ambiance and perceptions*

The evolution of LED lighting now provides the opportunity for lighting schemes to have variety of temperatures and with this to alter the ambiance or streets and areas. Eindhoven has established a European test bed for LED (Red Green Blue- RGB) public lighting (Strijp-S, Torenallee) so that experiments can be carried out with sophisticated mood settings. This has and will provide the opportunity to carry our further research to understand the health, well-being and marketing benefits of RGB LED lighting. The Torenallee(TCS 6.6) was designed to help lighting engineers and politicians/residents/stakeholders to start to understand the variability, acceptability and ambiance associated with different lighting temperatures.
The BLISS partners carried out a sophisticated technical and stakeholder evaluation of a diversity of different lighting installations. The TCS 3.4 has provided empirical evidence that the views and preferences of professionals and residents often diverge and that it is critical to involve residents and businesses in the design of lighting in their areas. (See figure 3.3).

Torenallee Strijp-S, Eindhoven.
LED's can be controlled by the backbone to change the colour and ambiance of lighting. (TCS 6.1)

Figure 3.3 Differences of opinion

Initial Thoughts	
Residents' Focus Group	**Professional Focus Group**
"Very good vision. Very safe. Best street so far." **(60W CPO lamps)**	"Not impressed. Uniformity very poor. Zebra effect." *Engineer* **(60W CPO lamps)**
"Burglar's paradise." **(70W SON lamps)**	"Adequate, friendly." *Consultant* **(70W SON lamps)**
"Very bright, can see everything. Safe!" **(Speed Star Eco LED)**	"Poor, uninviting, cut-off, too severe." *Consultant* **(Speed Star Eco LED)**

3.5.8 Crime

The partners now better understand how changes to public lighting installations affect local residents' perceptions of the safety of an area. Partners explored stakeholders' perceptions of the safety of areas both in day time and at night, and before and after the new installations were made. As in many urban areas, some streets are perceived to be unsafe both in the day time as well as at night. For lighting designers and politicians this is an important lighting design driver and recognises that the fear of crime and personal safety emanates from much more than just the quality of the lighting. It became clear only in the UK are detailed crime and accident databases available to designers. This allows for multiple beneficiary outcomes between all agencies where required.

Although each partner used bespoke questions, all were carefully constructed to provide empirical evidence to influence the design – and to validate the completed installation. (Table 3.4) The installation of lighting in the city park at Aarschot (TCS 8.6) illustrates that although users acknowledge that the investment has dramatically improved illumination levels, saved 53% of energy and that most feel it is comfortable on the eye, there has been no improvement in their perception of park safety at night. And so although 95% of people consider the lighting to be an improvement it has not materially changed their perception of its safety. It's important to contrast this with the investments in Werchter, Rotselaar (TCS 7.1) and Wakkerzeelsebaan, Leuven (TCS 8.4).
Both of these investments have resulted in all of the residents now feeling safe out alone in the streets at night – up from 60-70%.

The Partners examined data on crime to inform and drive their lighting designs. What has become apparent is that data on crime should only be used as a secondary design driver. Not only is the incidence of crime generally poorly reported and recorded, but the correlation between crime incidents and lighting is difficult to determine. This is illustrated by the stakeholder research at Strijp-S: residents cited that many of them had suffered thefts and vandalism to their bikes, but few reported these as 'crimes' and if reported, certainly not only related to 'bad' lighting. There are no records on the police database. (TCS 6.6)

Access to data on crime is also an issue. Although some cites now have information on crime incidents available to the general public online through maps, only the UK partner has benefited from this service where historically multiple outcomes have been achieved. There were relatively few crime (or accident) incidents prior to the investments – generally less than 5 each year. Close examination of these by the partners during their design development process did not identify any trends or correlation with the lighting schemes. There is also a time lag between accidents and crime incidents and the data being publically available. This has meant that BLISS partners have not been able to confirm or otherwise a correlation between crime / accidents and improved lighting for their investments. Although for all investments there has been a reduction in reported crime and accidents, the low numbers mean that this is not statistically significant.

"I don't feel safe in the park, day and night."

"very beautiful luminaires."

Schréder Perla luminaires in the city park. Aarschot (Interleuven). (TCS 8.6)

The characteristics of crime incidents are recorded in more detail in the UK than in other partner countries in the project where historically multiple outcomes have been achieved through linked up service providers.
The characteristics of the crime incidents collected in the UK illustrate how these can be used as a design driver for lighting design;
UK Crime - Recorded Characteristics [10]

Main Crime Categories:

- *Burglary from a dwelling (Ranking 5)*
- *Theft of a Motor Vehicle (Ranking 4)*
- *Theft from a Motor Vehicle (Ranking 3)*
- *Criminal Damage (Ranking 2)*
- *Rowdy & Inappropriate Behaviour (Ranking 1)*

The crime statistics during the hours of darkness are ranked high/ medium/ low within each local 'ward' of the municipality based on the 5 crime types.
Each crime type is weighted 1 to 5 as identified above, and then a correction factor is added to include the road length depending on the number of public lighting columns within each road.

- *Top 16% of roads = High*
- *Middle 68% of roads = Medium*
- *Bottom 16% of roads = Low*

(Monthly data is available from 2008; Dawn / Day / Dusk / Night: Based on 1 hr time bands taking into account sunrise / sunset times).

New white light Cosmopolis 60 W lamp providing high-quality colour rendition and illumination compared to SON light source in surrounding residential areas. St. Helens. (TCS 7.1)

10 *Reference from St. Helens*

Table 3.4 Stakeholder questions and underpinning logic

Question	How does the answer help to influence
Do you feel safe walking here alone during the day?	What is the perception of safety What is the correlation between perception and evidence /crime data? Do perceptions vary between stakeholders age/gender
Do you feel safe walking here alone at night?	What is the perception of safety What is the correlation between perception and evidence /crime data? What is the difference between day and night –how significant is this?
Does the lighting appear comfortable on your eyes?	Satisfaction with the ambiance of the lighting (Obtrusive light considerations / illuminance level/light source/ luminaire design)
Does the lighting illuminate your property and access?	Satisfaction with the distribution of columns (Light spill, luminaire design/ lighting level)
Does the lighting let you see people and objects at a distance? .	Satisfaction with the level of illuminance and colour rendition of the lamps
Does the lighting appear patchy/uneven?	Satisfaction with the uniformity of the illuminance
Does the lighting show colours correctly?	Satisfaction with colour rendition levels
Using a scale of 1 to 10, please rate how bright the public lighting appears (1 = very dark, 10 = very bright).	Measurement of marginal change in perception of brightness
Using a scale of 1 to 10, please rate how satisfied you are with the lighting (1 = very dissatisfied, 10 = very satisfied).	Measurement of overall satisfaction

*HOV bus lane crossing with RGB LED's in the ground.
Strijp-S, Eindhoven.
(TCS 6.7)*

3.5.9 Innovation

One of the design drivers for the BLISS project has been to identify emerging needs in public lighting and stimulate the corresponding technological development of new lighting solutions and to test their acceptability. Three of these innovations (HOV bus lane, ViviLumen and Crystal) are described in the TCS 6.3. In doing so the evaluation has started to understand the potential of these innovations to deliver energy savings.

Innovation by its nature is unpredictable in both outcomes and timing – successful research and development requires conventions and standards to be challenged and, dismantled and for new equipment, technology, control methods, and tools to be tested. This innovative process occupied much of the early phase of the BLISS project for Eindhoven at Strijp-S where the expert and observer meetings brought together a heterogeneous group of stakeholders from universities (e.g. Belgium, Holland), market parties and government. These triple helix based meetings were focussed on stimulating innovation prototyping and testing in real life 'living labs' in Eindhoven at Strijp-S. (TCS 6.3).

HOV bus lane crossing is RGB LED's in the ground react to sensors and pedestrians crossing. To replace traditional crossing lights. Strijp-S, Eindhoven. (TCS 6.7)

With the need to engage consultants in adaptable frameworks that were designed to bring forward innovative designs the procurement rules and norms had to be challenged. New working relationships between academics, stakeholders, politicians and officers had to be established and boundaries for the innovation agreed. Emerging out of this design process has been this Final Guide for municipalities wishing to innovate in public lighting design.
BLISS learned that adopting an open shared innovation model can exclude established and multinational lighting manufacturers as the timetables and agendas are very different. We also learned that intellectual property issues and long term delivery contracting can obstruct innovation, that tendering and legislation may also frustrate innovation. Innovation routes need to be uninterrupted. Innovation in lighting starts with an idea and the route to prototyping needs to be clear of bureaucracy and red tape. It also needs trust and stability in the partnership. After finalising the prototyping phase, the IP holder(s) need to translate the idea to a high-end and efficient production line. These two phases takes an enormous amount of energy and funding.

3.5.10 Accident characteristics and cost

St. Helens identified during the early stages that the police in the UK record the characteristics associated with accidents in more detail than police in the other partner areas and share this data. Indeed a long governmentinitiative to reduce road accidents in the UK has brought close working between traffic engineers and professional lighting engineers. This approach was driven by key performance targets for which grant were awarded.

The absence of data on the lighting at the time of accidents for most of the partners has limited the extent to which accidents statistics can be used as a design driver. St. Helens has been able to monitor the marginal impact of new lighting designs on accident statistics. The TCS's from St. Helens demonstrate that using the data where there are specific trends, lighting design can assist in a reduction in accidents. St. Helens have used the following reference criteria in influencing their lighting designs:

- Accident Severity: Slight/ serious/ fatal
- Road Classification: Single carriageway/ dual carriageway/ roundabout
- Lighting Conditions: Daylight/ dark, lights lit/ dark, lights not lit/ dark, unknown
- Weather Conditions: Fine/ rain/ snow/ fog
- Road Surface Conditions: Dry/ wet/ snow/ ice
- Junction details: Not junction/ junction/ T junction/ staggered junction/ multi-way junction/ roundabout
- Junction control: Automatic Traffic Signals/ give way
- Speed Limit: 20/ 30/ 40/ 50/ 60/ 70mph

Vivi Lumen consists of 6 poles that create a certain atmosphere by simulating the time of the day. The 25 W LED "toplight" provides the necessary functional street lighting. Strijp-S, Eindhoven. (TCS 6.7)

A "carpet" has a coil conducting alternating current wich induces a small current in the coil of the crystal driving the LED's in the crystal. Strijp-S, Eindhoven. (TCS 6.7)

6 Illuminated poles with 25 W LED "toplight" (functional street lighting) with programmable/sensor driven RGB's in the pole. (TCS 6.7)

3.5.11 Functionality and lighting quality targets

Road classification:

All partners have based the design of their new and replacement installations on the reference lighting category for the relevant road classification. [11]
Legislation and best practice guidance at International, national and local level has an important influence on assisting municipalities in developing their forward energy efficient lighting policies. It offers guidance and advice in terms of determining the correct lighting classification and acceptable variance tolerances to be applied at different times of the night, guiding lighting professionals in the development of a robust design selection process and risk assessment protocol.

Colour quality:

Through a series of structured scheme review workshops and site visits based on individual situations i.e. residential, partners reviewed the various different colour characteristics available from High Intensity Discharge Lighting (HID) and LED's light sources. This collaboration led to the development of a set of simple lighting acuity test which were used by partners during initial evaluations and stakeholder consultation exercises. Although manufacturers and lighting professionals may consider that LED luminaires offer improved colour rendition, over Ceramic Metal Halide for example, residents sometimes did not notice any significant difference or agree. (TCS 3.4).

3.5.12 Environmental targets

BLISS partners have grown to appreciate the importance of setting environmental targets for a new or replacement lighting schemes (TCS 3.5/3.19/3.18). The simple E1-E4 classification as set out above has proved to be only the starting point for considering what targets to set for lighting designs. The scope of the design options can be very extensive and that the design development process needs to be informed by the relative importance of environmental targets. The TCO appraisals carried out by partners highlighted the high financial costs, nuisance, urban disturbance and adverse environmental impacts associated with replacing existing underground power supply systems. A transition to AIL requires new underground power supplies and control cabinets. Partners have explored the balance between the significant adverse environmental installation impacts as compared with the long term environmental (and energy reduction) benefits associated with dimming etc.

Maintenance:

The Total Cost/Value of Ownership reflects that both planned (cyclic) maintenance and reactive maintenance (attending to faults) during the lifetime of the installation is one of the most significant environmental impacts associated with lighting schemes.

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11. http://www.ltblight.com/English.lproj/LTBLhelp/pages/EN13201.html

Although manufacturers provide guidance on the anticipated maintenance for their components, partners have used their experience to moderate these claims in determining the more likely intervals and costs. Partners visited the Laboratories of Ghent University who undertake substantial test work on behalf of manufacturers and attended a workshop led by Infrax and Eandis who both undertake multi-dimensional monitoring of the environmental and financial impacts of maintenance. This revealed that rarely does the independent testing correlate to manufacturer's claims when tested across a range of scenarios.

The other main considerations have included reuse of elements, specifying relevant eco efficiency standards, recycling components, ecological impacts and minimising light pollution. The key learning from BLISS is that The Total Cost/ Value of Ownership should reflect both planned (cyclic) maintenance and reactive maintenance (attending to faults) during the lifetime of the installation as one of the most significant environmental impacts associated with lighting schemes.

St. Helens has a sophisticated approach to assessing the financial costs and environmental impacts of maintenance and includes the following criteria in their design development:

Figure 3..4 Environmental Criteria in Maintenance (UK example)

Planned (Cyclic) Maintenance

1. Lamp Replacement (3 Yr / 4 Yr / 6 Yr / 12 Yr+)
2. Lantern Clean (3 Yr / 4 Yr / 6 Yr / 12 Yr+)
3. Routine Visual Inspection (3 Yr / 4 Yr / 6 Yr / 12 Yr+)
4. Electrical Test & Inspection (6 Yr)
5. Fatigue Testing (20 Yr +)
6. Re-Application of Paint System (20 Yr +)
7. Lantern / Control Replacement
8. CMS Service Level Agreement
9. Traffic Management
10. Impact Protection Inspection
11. Night Inspection Regime
12. Works Ordering & Supervision

Reactive Maintenance (Fault Repair & Emergency Works)

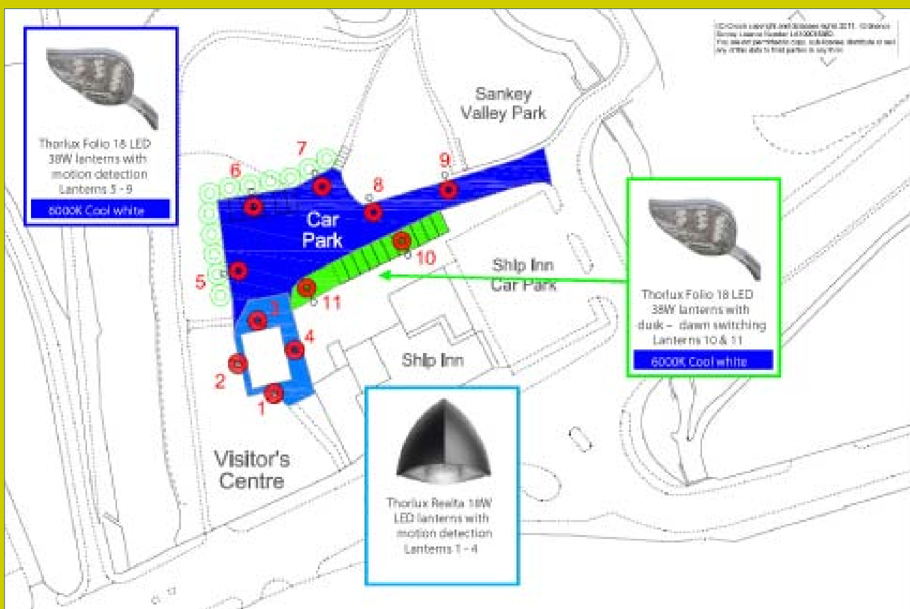
1. Light Source Life Expectancy
2. Maintenance Strategy
3. Quality of installed equipment
4. Quality of electrical infrastructure
5. Age of Installation
6. Location vandalism rating
7. Location accident rating

Reuse:

The partners explored the financial costs and environmental benefits associated with the reuse of luminaires, reuse of columns, the reuse of existing power infrastructure (e.g. TCS 7.6) and the reuse of ballasts (3.5/3.19/3.18) as part of their investments.

Recyclability:

All partners have had regard to the relevant eco-efficiency standards in specifying the performance requirements for all lighting components. In doing so they have sought to maximise the recyclability of components.

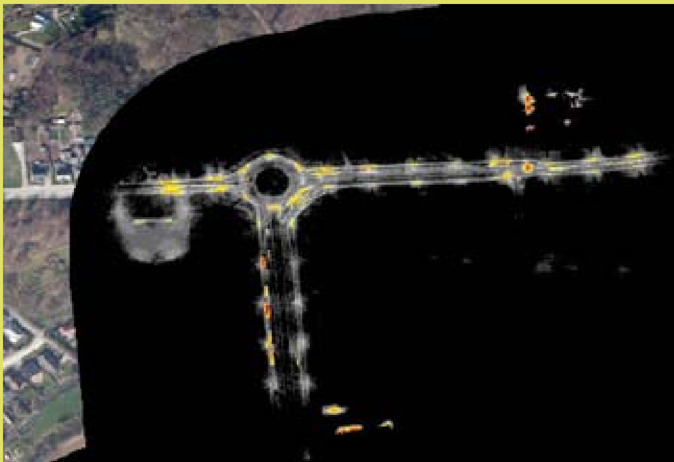


Wildlife sensitive lighting scheme that delivers 24% energy saving. St. Helens. (TCS 5.1)

Ecological impact:

The possible adverse impacts of lighting on wildlife and bats (in particular) have been given different weight by the partners in their design process.
Some investments have been in places where fauna is known to be sensitive to light (TCS 5.1). The use of PIR and dimming (TCS 8.4.) provides the opportunity to minimise adverse impacts whilst the introduction of IP controls for each luminaire would allow future adaptation in response to changing wildlife patterns.

Light Pollution:
The delight of being able to see the night sky relies on public lighting being designed to minimise light pollution (TCS 8.3). Minimising the amount light commensurate with safety, comfort and ambience has been a tension throughout the project where many residents and stakeholders have demanded illumination levels and lighting classifications well above the norm for the streets and car parks. (TCS 4.1).



Exessive lighting levels can be identifed using specialist aerial photography. St. Helens. (TCS 8.3)

3.6 Design Standards

Across Europe a European Standard (EN) is a standard that has been adopted by one of the three recognised European Standardisation Organisations (ESOs): CEN, CENELEC or ETSI.

European Standards are a key component of the Single European Market; although rather technical and often unknown to the public and wider stakeholders they are actually crucial in facilitating standardisation and hence require a greater visibility amongst lighting professionals as well as manufacturers inside and outside of Europe.

A standard represents a model specification, a technical solution against which a market can trade. It codifies best practice and trans-national forward thinking in terms of safety, lighting quality, product compatibility and safe disposal.

The document CEN/TR13201-1:2004 " Road Lighting Part 1: Selection of lighting classes" prepared by Technical Committee CEN/TC 169 "Light and Lighting" recommends the lighting classes set out in the standard EN13201-2 and gives guidelines on the application of these classes.

In essence EN 13201 sets out the specifications for different lighting classes, while national guidance recommends how these classes may be applied within their own individual areas.

Since the launch of EN 13201 in 2004, power consumption and environmental aspects have become even more important and at the same time, the improved performance of light sources, luminaires and especially the introduction of controllable electronic control gear, has made it possible to introduce adaptive lighting for all Public Lighting situations.

Municipalities are encouraged to use the experience gained in extensive studies at several European SSL test sites to define both minimum and specific performance requirements in line with existing LED lighting standards or pre-standards from European (CEN, CENELEC) or international (IEC, CIE) standards organisations.

BLISS partners considered the IEC pre-standards on performance requirements for LED modules and LED luminaires, together with the test methods and conditions to show compliance. These criteria, together with the specification of minimum performance requirements for the project at hand have been used as a basis for the SSL tender and procurement specifications.

Throughout the project BLISS partners have looked at the design, test, and assessment standards that are conventionally used in their municipalities and member states. Partners have identified where these standards etc. need revising /adapting and up-dating;

3.7 Better Lighting for Sustainable Streets: Recommendations

1. **Municipalities** should use and adopt the BLISS design process as set out in this guide to deliver cost effective energy efficiency savings in public lighting and to gain support from stakeholders for the changes and investments.
2. **Lighting professionals and research institutions** should promote the BLISS design process set out in this guide.

Total Cost of Ownership

3. **Municipalities** should use TCO (as a minimum) to inform their decision making for public lighting and as a basis for their investments.
4. **Lighting professionals and research** institutions should share their experiences and best practice of TCO models.
5. **The EU** should promote a standard model for TCO in public lighting.

Total Value of Ownership

6. **Municipalities** should use the BLISS TCS's to explore the potential of TVO to inform their decision making for public lighting and as a basis for their investments.
7. **Lighting professionals and research institutions** should undertake studies to establish benchmarks and models for TVO in public lighting.
8. **The EU** should support the development of TVO.
9. The EU should support the development of an agreed standard for energy efficiency calculations and the use of annual / forecasted consumption indicators.

Borrow to invest

10. **Municipalities** should use TCO/TVO as the basis of a business case to invest in energy efficient lighting
11. **Member states** should support investment in energy efficient lighting and business cases

Hoeledensebaan, Kortenaken. (Interleuven).
New and old lighting scheme.
(TCS 7.11)

4. What lighting equipment should I choose?

4.1 Introduction - What is it important to know

Before selecting new or replacement public lighting equipment municipalities need to determine the required lighting profile as part of the design selection criteria and where applicable undertake a detailed condition survey of the existing asset to determine its condition and existing energy profile.

BLISS has confirmed that in designing new and replacement lighting schemes it is important to ensure that the relative importance of each of the design drivers is agreed following a review of current legislation, best practice guidance and local strategy. The location and conditions should be evaluated and consultation with identified Stakeholders undertaken. BLISS partners have recognised that municipalities need to keep their strategic lighting strategy sted (keep and) plan under continuous review as legislation, local conditions and equipment specifications dictate. The potential TCO / TVO benefits need to be considered based on the situation and the approach to be taken need to be agreed
following a review exercise to consider the available options.

Understanding the political ambition for lighting is important.
Eindhoven's ambition is to have a public lighting system that is not changing users' perception but to have a lighting system that knows how to respond to people's (even individuals) behaviour. In the same way the lighting will also respond instantly on weather conditions and as other things happening in public space. This is not the ambition of the other partners and so Eindhoven's selection of equipment is very different to that of the other partners.

The intense marketing and lobbying of luminaire manufacturers and proponents of AIL systems needs to be balanced with objective and independent advice, product evaluation and research on the suitability and appropriateness of new and emerging equipment. It is important to be able to call upon the services of independent experts to moderate the pressures from companies. This will allow the individual characteristics of manufacturer's components to be objectively appraised.

All the partners have experienced considerable pressure from manufacturers to purchase luminaries, infrastructure and control systems that would have been unsuitable, inappropriate and expensive for the site and future use.

Through shared knowledge exchange partners acknowledge that there are a number of approaches that need to be considered when replacing existing public lighting schemes; from simple light source replacement, through the retrofit of Intelligent Control through to the adoption of a Central Management System featuring Solid State Lighting. It is recognised that there is an important precursor before adopting an Intelligent Lighting System approach that requires significant investment in changing attitudes, improving skills, creating new partnerships, and service delivery models.

- Training, education and awareness in the various energy efficient approaches available is crucial – for lighting professional, policy makers and stakeholders enabling informed decisions to be made based around; local conditions.
- Municipality's aspiration and available funding.
- Energy efficiency in public lighting will be achieved by replacing existing light sources, control gear, luminaires and control functionality with equipment offering reduced power consumption, increased efficiency and greater flexibility to meet the needs of the local community and wider stakeholder demands.
- Municipalities need to consider equipment, availability, functionality, maintainability, life time cost, robustness, interoperability, scalability and sustainable qualities.

4.2 Light Sources

Today's public lighting across Europe commonly consists of High Pressure Mercury Vapour (MBFU) lamps, Low Pressure Sodium (LPS) and High Pressure Sodium (HPS). The introduction of a number of new-generation ceramic metal halide lamps offering a white light plus the emergence of LED as a viable light sources has given professional lighting engineers increased scope to select a lamp / luminaire / control combination that matches the light output to the surrounding environment ensuring optimised energy efficiency savings can be achieved.

A varied selection of lamps are available each with its own unique set of characteristics and professional lighting engineers need to be careful to select the right combination based on the approach to be taken.
Table 4.5 is a summariy of the main lamp characteristics.

4.3 Lighting Equipment

Light Emitting Diodes (LEDs)

Solid-state semiconductors known commonly as Light Emitting Diodes (LEDs), are challenging the place of incandescent, fluorescent, and High Intensity Discharge (HID) light sources that have dominated lighting practices over the last hundred years.

Outdoor LED luminaires are now able to be considered for a full range of situations including strategic and primary traffic routes, commercial centres, residential areas, green spaces and parking zones as well as architectural and sports lighting.

LEDs are now reaching market maturity in terms of cost and product reliability. Compared to traditional lighting. They are offering substantial energy savings particularly when combined with adaptive controls, offering improved lighting quality, and a platform for further innovation and flexibility.

Table 4.1 Light Source Type Summary

Light Source	Life (Years)	Energy Efficiency Label	Light Output Efficiency	Colour Appearance	Run-up time	Restart Time	Variable Lighting Level (Min dim level)	Advantages	Disadvantages
High Pressure Mercury (MBFU)	2 to 4	8	Low 36-55 lm/w	White	5 mins	Up to 10 mins	NA	High intensity	Contains mercury Poor efficiency
Low Pressure Sodium (LPS)	3	A+ to A++	High 129-176 lm/w	Orange	Up to 14 mins	Instant to 15 mins	NA	Direct replacement LPS Excellent efficiency No Mercury	Poor colour appearance / rendition Bulky size Poor optical performance – significant amount of light spill
High Pressure Sodium (HPS)	4 to 6	A+ to A++	Medium 81- 137 lm/w	Yellow	Up to 12 mins	30 secs – 5 mins	20% light (35% power)	Direct replacement HPS White light alternative available No lead	Average optical performance Average colour appearance Contains mercury
Conventional Metal Halide (CDO/ CDM)	2.5 to 5	A+	Medium 88 – 113 lm/w	White	3 mins	Up to 15 mins	NA 50% light (60% power) (CDO)	Direct replacement HPS Good colour rendering properties	Contains mercury and lead
New Generation Metal Halide (CPO)	3 to 6	A+	Medium 110-120 lm/w	White	2 mins	Up to 15 mins	50% light (60% power)	Excellent colour rendering Compact size	High initial cost Dedicated control gear Contains mercury
Fluorescent	2.5	A to A+	Medium 67-88 lm/w	White	Few seconds	Few seconds	Up to 50%	Low initial cost Excellent colour rendering Near instantaneous ignition	Contains mercury
Induction	12.5+	?	High	White	Instant	Instant	NA	Long life Good energy efficiency	High initial cost Large light source Contains lead Large diameter fluorescent tubes
LED	12.5+	A++	High	White or RGB	Instant	Instant	0% to 100%	Small light source Excellent energy efficiency Excellent functionality; dynamic switching, intensity variance, directional focus and colour control Good Life expectancy No mercury - Easily to recycle - Excellent optical performance - Little upward light	High initial cost Use of raw materials
OLED	Organic light emitting diodes (OLEDs) are electronic devices made by placing a thin film of an electro luminescent organic material between two conductors of different work functions. OLEDs are still in their infancy in terms of exterior lighting applications. This relates to their technical properties, including luminous efficacy and lifespan plus the relative high cost of OLED elements. It is possible to see the huge potential of OLEDs acting as a source of inspiration not only for conventional luminaire manufacturers but also for lighting designers and architects. The possibilities of these light sources go way beyond current applications, opening up a much greater scope however it has not been possible to realise the potential of OLED during the BLISS project timeline due to the lack of product development for the public lighting marketplace.								

Despite the clear advantages of LEDs, adopting new technology and building user confidence takes time! The introduction of new innovation within an established market place is usually met with a degree of scepticism and perceived risk. Useful innovations rarely achieve market success without significant long-term investments in product and market development.

During the emergence of LED technology, professional lighting engineers have been deterred by the perceived issues of retrofitting LED light sources and associated drivers into conventional luminaire enclosures. As LED technology has advanced and suppliers gain a greater understanding of component functionality a number of retro fit pilot installations have been installed, however these have mainly focused around subway and tunnel installations.

White Light

In recent years, two independent pieces of research have been undertaken to understand how 'white' light can improve pedestrian's safe route of passage. The research has focused around the spectral power distribution (SPD) of light sources and improved brightness (perceived safety), obstacle detection and facial recognition (to judge intent). Human sight works differently during night and day. During the night, we see mainly via 'scopotic' (or brightness) vision. This vision is most strongly developed in our peripheral vision and we perceive light from the blue spectrum as being brighter than yellow light. During daytime, we see via our 'photopic'(or image) vision. This vision is most strongly developed in our direct line of sight.

The publication of the UK's road lighting standard "BS 5489-1:2013 Code of practice for the design of road lighting Part 1: Lighting of roads and public amenity areas" in Dec 2012 introduced the Scopotic / Photopic (S/P) ratio which is the ratio of the perceived brightness in the peripheral area compared to direct vision area.

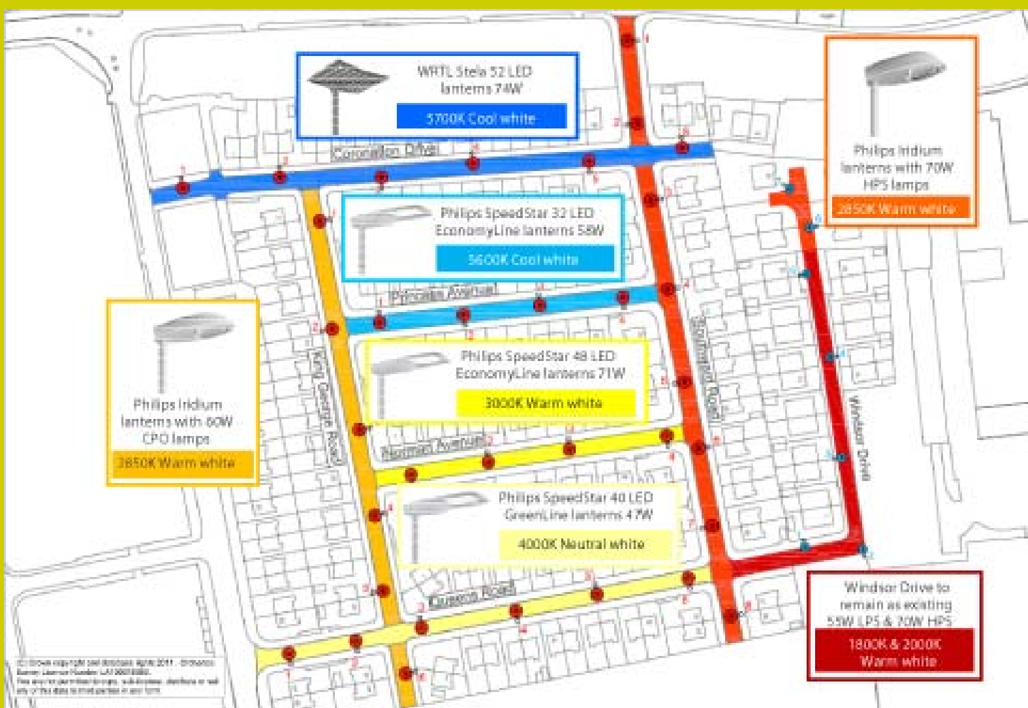
It can be claimed that luminaires with higher S/P ratios need to provide fewer lumen to reach the same level of perceived brightness in comparison to luminaires with lower S/P ratios.
We should remember however that currently the majority of lighting standards do not make any allowance for this effect and therefore lighting design should be to photopic levels as currently practised and it is important to note that the European road lighting standard EN 13201 does not take any consideration of S/P ratios and they cannot be used).

Changeable White

Tuneable white luminaires are capable of working in at least two different light temperature zones (e.g. warm white, 3000 and cold white 6000 Kelvin).
These provide an opportunity to tailor-make the white light settings.
In the BLISS project various colours of white (e.g. from 2700K to 6000K) have been compared (TCS 3.4) and tuneable white luminaires have been installed to research the perception of users to warm and cold white light (TCS 6.4).
These offer exciting possibilities for flexible adaptable lighting to meet the needs of users.

Luminaires

There is a huge range of luminaire types and designs, each with their own characteristics. There are four principle components in a luminaire: the housing, control gear, lamp and reflector. Luminaires should be manufactured from robust, fit for purpose sustainable materials and should offer flexible, excellent optical performance in combination with an attractive daytime appearance. All components need to be compatible with each other and guaranteed accordingly offering combined control functionality, interoperability, and scalability to maximise efficiency savings. In conventional luminaire design, not all of the light emitted by the lamp is emitted by the luminaire; this is due to losses caused by inter-reflection and absorption.



Plan 1, Scheme was to evaluate different colour temperatures within a controlled area in relation to the feelings of safety, focussing on public consultation to gauge citizens' perceptions. (HPS, CPO and LED), in six variations of colour temperature; warm white (<3300K), neutral white (3300K to 5300K) and cool white (>5300K) - 10% energy savings). St. Helens. (TCS 3.4)

4.4 Lighting control

Control Functionality

The most efficient public lighting is controlled via time switches or Photo Electric Control Units (PECU's) that control individual lighting points or a group of units. PECU's have become more intelligent and have been combined with intelligent control gear (ballast / drivers) to increase the flexibility of a lighting system (standalone or centrally controlled).

Control Gear

In a similar way to a laptop power supplys, the control gear transforms the mains electrical supply. A ballast which stabilises the current can be used in conjunction with other components to manage the lamp.

Intelligent Ballast / Driver (Stand Alone)

If a municipality is looking to achieve energy savings without major changes or investments in new infrastructure, standalone controls should be considered – these operate independently, enclosed in the luminaire, varying the light based on a pre-defined schedule. All the necessary components are integrated into the light point, and there is no need for any additional system maintenance.

Central Management System (Networked)

Central Management Systems (CMS) also known as Remote Monitoring or Telemanagement is a wide area lighting control system, capable of two way data communication allowing the end user to alter the intensity / colour combination of individual or groups of connected luminaires. Providing 360° control functionality and real time automatic notification reports on the health status of each and every public lighting luminaire, traffic sign and illuminated bollard connected into the system.

CMS Architecture can include **Roadside Equipment**: luminaire, light source, intelligent ballast / driver, **Power Network:** private Cable (PC) or Distribution Network Operator (DNO), **Local Control System (LCS)**: communication between the light source and the intelligent ballast / driver via an interoperable (open) protocol able to communicate with the latest light source technology allowing remote configuration and diagnostics reporting, **Central Supervisory Control System (CSCS)**: to achieve data exchange between individual lighting points and the user a two way data communication platform needs to be established either via secure structured, standards based wireless networks - Radio Frequency (RF), additional dedicated hard wired control (copper wire, fibre optic) via an approved protocol or the transmission of mains borne signalling over a private network system or local electricity distribution network (following operator approval) **Communication Network**: the communication link interface between the site base equipment and the Municipalities back office; Use of wireless networks or a hard wired Ethernet-type communication network, in both cases there should be Internet connectivity.

Constant Light Output (CLO)

All light sources experience lumen depreciation (a reduction in light output over time). To ensure the minimum required light levels in an installation, most lighting designs are calculated based on the light level at end of the lamp's useful life (normally the L70 point: 70% of the initial lumens). This means that the system consumes more power than necessary, wasting as much as 15% of energy on average during its lifetime. CLO functionality compensates for this light loss, ensuring that both High Intensity Discharge (HID) lamps and LEDs will always deliver the necessary light level. By taking into account the lumen depreciation, the intelligent ballast / driver can be programmed to start at a dimmed level and gradually increase power over the life of the light source, saving energy and extending the lifetime of the system.

Adjustable Light Output (ALO)

When the light level requirement for a particular solution falls in between the lumen packages delivered by standard lamp types, it is possible to customise the power level of the lamp. The ALO feature can be programmed to the desired light level, creating a virtual lamp. Using ALO allows professional lighting engineers additional flexibility and can achieve additional energy savings.

Motion Detection

Motion detection is device that detects moving objects, particularly people. Recognition information can be relayed between lighting points to account for the trajectory and velocity of pedestrians and vehicles, allowing both reaction and anticipation.

Alternative Energy

The recent innovations in Solid State Lighting technology have made it possible for the further consideration of alternative energy from renewable resources. Energy collection (solar / wind) converts the energy produced into useable electric energy, which is then stored into Energy Storage devices (e.g. high energy density batteries) during the day. During the night, this stored energy can be used to power LED luminaires from the batteries through converter circuitry or feed back into the energy grid.

4.5 Smart Lighting

TVO can provide an indication of the values that can accrue from lighting and in particular smart lighting. It is only possible to provide a brief outline of the potential of smart lighting. Upgrading lighting so that it is future proof requires that this is done not in isolation but integrated with other communications, data, and infrastructure services recognising that every aspect of life is becoming digital and can be interrelated. The benefits of open programming protocols and shared platforms to promote innovation in the control of public lighting has been demonstrated with the BLISS projects in Strijp-S. (TCS 6.1 et al).

These have confirmed that the benefits associated with smart lighting will include:

- IP address for all lighting points
- the ability to include a tri-coloured LED to communicate visual information such as;
  - Blue – low temperatures,
  - Amber – weather warning – check radio etc.,
  - Red – emergency; "check radio/TV/web." Or
  - to indicate the location of an incident to emergency services arriving at scene.
- full remote control / monitoring functionality & fault detection
- variable light output with recorded levels for energy billing
- new lighting application using colours to attract and engage with citizens
- potential to control level of lighting based around real time traffic flow, congestion and pinch points - realising additional energy savings
- potential to control level of lighting based on emergency incident requirements
- potential to control level of lighting based on increased footfall levels – motion detection / sound / Smart APP interface - Smart City travel app and personal travel plan
- Interface with commercial area premises lighting, route marking to events, available parking etc.
- lighting profiles / colour management / actions can be added to municipality plans
- feeds to and from Smart Cities intelligent communications network
- respond to weather conditions; intensity and colour, yellow for fog etc.
- data collection via additional devices using the communication network
- shared cost of communications e.g. between traffic signals and public lighting

4.6 European Lighting Policy

One of the key steps towards the deployment of a public lighting strategy is a municipality gaining a clear understanding of current EU policy and determining its impact based around any shortcomings associated with their existing lighting asset profile. Once an asset evaluation has been completed the next step is advocated to be the preparation of a detailed technical plan and associated business case(s) with a clear appreciation of what the new public lighting strategy / deployment should provide both in the short and the longer term.

The current European Union (EU) Policy context is particularly favourable for the deployment of innovative outdoor lighting solutions. The Green Paper 'Lighting the Future' [12] laid down the basis for the widespread deployment of high-quality Solid State Lighting (SSL) in Europe. The recent EU Energy Efficiency Directive [13] asks authorities to purchase only products, with high ratings for energy performance, consistent with the Energy Labelling and Eco-design Directives, which also strongly support the transition to high quality LED lighting in outdoor and indoor residential installations. The new EU regulation for Energy Labelling of electrical lamps and luminaires explicitly includes LED

lamps and modules. It defines two new energy classes, A+ and A++ (mainly populated by LEDs).
The gradual phase-out of inefficient directional lamps is expected by September 2016, when only class B or higher will remain so that the superior energy efficiency of LEDs can be highlighted. The quality of the lamps will be assured by the new Eco design regulation for directional lamps and LEDs, which completes and complements the previous regulations for non-directional and professional lamps.

Green Public Procurement (GPP) [14] criteria exist for indoor and public lighting and for traffic signals. They provide state-of-the-art specifications for lighting products and services with a reduced environmental impact throughout their life cycle that public authorities in EU Member States may wish to consider when procuring such goods.

The ErP - Energy related Product - legislation (Commission Regulation (EC) No 245/2009) promotes energy efficiency and energy-efficient products in terms of their environmental impact. As part of this policy a number of popular High Intensity Discharge (HID) lighting types will have to be phased out by 2017 including selected high-pressure mercury 'standard' High Pressure Sodium (HPS) and Ceramic Metal Halide (CMH) unless minimum specified efficacies can be reached based around identified lamp wattage and base type.

Leading supplies have identified which of their products will be affected by this initiative and guidance is available regarding alternative retro fit 'high performance' HPS / CMH lamp only or lamp / control gear replacement packages.

4.6.1 What energy savings were made

St. Helens

A wide range of different approaches and technologies have been used in St. Helens to reduce energy consumption from public lighting. These have delivered energy savings of between 66% to 10%. Full details are contained with the TCS's and the Final Report for the BLISS project. St. Helens as part of their work on the project have also identified the scale of the energy savings that can be achieved using a selection of simple approaches and technologies and these are set out in figure 4.1 (page 72).

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12 DIR 2010/31/EU

13 Regulation 874/2012/EU of July 2012

14 GPP is a voluntary scheme at EU level see COM(2008) 400

2b > Lamp & trimming
- 3%

2c > Lamp & variable adaptive lighting
- 47%

3 > Luminaire
- 39%

4a > Motion detection
- 34%

4b > Central Management System
- 28%

8 > Decorative lighting
- NA - TVO considerations

Figure 4.1. Typical energy savings from different approaches

Eindhoven

The Strijp-S area was never a residential area but rather a relic of what once was one of the bigger Philips factory and laboratory sites. Therefore it is difficult to compare the lighting system in a meaningful way. However it is possible to compare roads with roads and parking spaces with parking spaces. Eindhoven transformed old parking lots into roads and vice versa at Strijp-S. At the same time they increased the uniformity in lighting (e.g. by reducing the distance between columns). Since the total volume of roads doubled from roughly 3 to 7 kilometres, the use of energy increased. However expressed as Watt per meter road, there's a slight reduction. The older schemes used about 6.25 Watt/metre; the new site is lit with a power consumption of about 4.20 Watt/metre. This gives a reduction of 33%, due to the introduction of LED and intelligent lighting systems.

Interleuven

The municipalities that make up the Interleuven consortium have made investments that have resulted in a range of savings in the energy consumed by the public lighting. Some of these schemes have resulted in savings of 7% where environmentaland design issues have limited the possibilities for energy savings. However with some investments the energy savings are as high as 82%.
What has become clear to Interleuven from participating in the BLISS project is that when the responsibility for financing the installation and operation of public lighting is shared between a number of agencies it is difficult to maximise energy savings.

Kaiserslautern

A modest but imaginative lighting investment has enhanced the appearance of the city centre, reduced graffiti and led to significant community support and interest in public lighting. Kaiserslautern like all partners has struggled to value and measure these benefits. The investment included some solar panels to offset some of the extra energy consumed and carbon emissions produced; however there has been an overall increase of 16% in the energy consumed.
This case study demonstrates the challenge faced by the BLISS partners and all municipalities in satisfying residents, solving urban issues, creating interesting streets and reducing energy consumption.

4.7 Recommendations; The way forward

BLISS partners see the public lighting in the future as an enabler, starting with a transition from analogue to digital, from HID lamps to a move towards solid-state lighting – all featuring adaptive intelligent lighting techniques either standalone or connected to a Central Management System.

BLISS partners see that in time the grid will become another IP platform connecting light, people and devices with the telecommunications and internet network. In some cases, cities are already building an "Energy Internet."
As data flows become horizontal and open source rather than closed and on proprietary infrastructure then public lighting, air pollution, traffic and waste management systems can connect and be smart. This will generate value in the form of additional operational savings or revenues from these enhanced service offerings.

However, for many municipalities and cities this vision is not yet even a dream, or on their agenda, let alone part of their thinking or plans. Barriers to the deployment of Smart Lighting are recognised and BLISS has focussed on both understanding these concerns and finding solutions: [15]

- A limited awareness amongst many municipal lighting departments and luminaire designers of the substantial benefits offered by SSL. The uptake of any new technology needs time and efforts to raise the awareness of users to its benefits compared to conventional solutions.
- The social and communication skills required to engage with stakeholders in the design process are both time consuming and new to many lighting designers and engineers.
- The up-front investment costs for SSL linked to intelligent lighting control are significantly higher than for conventional lighting, requiring a consideration of Total Value of Ownership (TVO) to determine the full potential economic and wider community benefits.

15 *Lighting the Cities Accelerating the Deployment of Innovative Lighting in European Cities June 2013*

- There is a wide variability in product quality and in the reliability of information provided by SSL suppliers and a lack of shared information on performance data of tested SSL products.

Moving towards smart lighting first requires municipalities to understand and manage their existing lighting –BLISS offers the following simple steps towards this:

- **Step 1. Understand your energy use.** Find out what public lighting you have, where it is installed and how it is used. Check the condition and operation of your asset and monitor performance to obtain a base case against which energy efficiency improvements can be measured.
- **Step 2. Identify your opportunities.** Compile lighting / energy profiles and assess the approaches available.
- **Step 3. Prioritise your actions.** Draw up an action plan detailing a schedule of improvements that need to be made and when, along with who will be responsible for them. Short-term actions could include writing a lighting policy and launching an awareness campaign, long-term plans will include feasibility studies, stakeholder engagement, design evaluation, equipment selection, programme management, scheme delivery and monitoring phases.
- **Step 4. If needed seek specialist help** from qualified professional lighting engineers.
- **Step 5. Make the changes and measure the savings.** Implement your energy saving actions and measure against original consumption figures. This will assist future management decisions regarding your energy priorities.
- **Step 6. Continue to manage your public lighting stockbord** emphasising the need for energy efficiency. Enforce policies, systems and procedures to ensure that your business operates efficiently and that savings are maintained in the future.

BLISS, bright ideas for planet earth.

5. Involving stakeholders in public lighting decision making

5.1 Techniques to Engage with Stakeholders

The unique aspect of the BLISS project was to seek our citizens' views and aspirations for public lighting provision. If we were to make a step change in lighting provision, it was essential to engage with our people and users. It was important that this was done extensively and across a range of demographics in order that robust opinion could inform the BLISS investments and also legacy projects.

The 2009 pilot schemes confirmed that significant energy and carbon savings (31% - 50%) could be made with the installation of white lighting sources (CPO and LED). These trials generated a 48% public response to 'before' and 35% response to 'after' questions and identified that residents' only concerns were with the "cut-off" from LED lanterns resulting in the fronts of their properties no longer being illuminated. In addition to significant energy savings, 53% of the public believed that the new lighting was better or slightly better. This initial stakeholder research confirmed that energy efficient public lighting could be provided which could also improve the perception of safety and comfort as well as safe movement of pedestrians and cyclists at night.

St. Helens appointed a consultant experienced in stakeholder engagement, to advise, design and undertake consultation/strategies for some of the early and more complex investments. Eindhoven appointed a specialist consultant to engage with stakeholders and interpret reactions to the innovative lighting at Strijp-S. In-house staff in Interleuven and Kaiserslautern carried out their engagement and evaluation based on the concepts and strategies developed.

Where partners were seeking stakeholder opinions on options for new lighting installations time and effort was generally taken to explain and demonstrate the innovations proposed. (TCS 3.4). When the views of stakeholders were reflected in the designs these schemes were received high levels of satisfaction through post survey evaluation. (TCS 7.1/7.6).

The BLISS partners each recognise that stakeholder engagement needs to be designed to reflect the extent that stakeholders can be given meaningful opportunities to be involved in providing their views and opinions on elements such as:

- **The existing base line installation** – safety at night, visibility and colour rendition, comfortable on the eye, lighting of properties and access
- **The improvements and changes they would like to see** - colour rendition, location of columns and aesthetic design of equipment

- **The promoters design objectives** – cost, energy efficiency, illumination levels, control, reducing crime and lighting, as a contribution to regeneration initiatives etc.
- **The completed installation** – post scheme review

Involving stakeholders in lighting design and evaluation is fraught with difficulties attempting to understand and normalise the bias and prejudice inherent in every stakeholder. Views and opinions of stakeholders are framed from their experiences and knowledge, aspirations, physical abilities, quality of sight and age. The partners were not expecting 100% agreement or unanimity in the opinions expressed and this was certainly born out in the consultations undertaken.

Method	Positive attributes	Negative attributes	Sample TCS
Internet survey(twitter/ Facebook etc.)	Cost effective Large samples/ populations can be surveyed Simple to design and distribute Simple to compare pre and post works responses Statistical significance can be calculated Option to cost effectively follow up for clarifications and to add value Analysis can be automated	Reliability can be questioned unless questions are carefully drafted to avoid ambiguities Response rates are generally low Quality of responses depends on high levels of; stakeholder interest, knowledge and understanding of existing and proposed lighting, , understanding of the written questions,	Torenallee TCS 4.2 St.Helens College
Postal surveys	Cost effective Large samples/ populations can be surveyed Simple to design and distribute Simple to compare pre and post works responses Statistical significance can be calculated	Reliability can be questioned unless questions are carefully drafted to avoid ambiguities Response rates are generally low but some BLISS projects achieved 60% which is well above average. Quality of responses depends on high levels of; stakeholder interest, knowledge and understanding of existing and proposed lighting, , understanding of the written questions, No option for follow up responses with verbal questions to clarify or add value Analysis is costly	TCS 3.27 Newtown Estate TCS 3.5/3.19/3.18 Ballast Bulk Change TCS 7.12 Kumtich, Tienen TCS 7.1 Werchter, Rotselaar
Focus groups (Open groups can be made up of self-selected individuals who are not representative of the population – alternatively careful selection can provide focus groups that are representative of sectors of the population)	Moderator can use structured and semi-structured questions to fully understand participants', views opinions and bias. Generates valuable qualitative and quantitative data Moderator can use the interview to provide background education/awareness information on lighting Interviewee can ask questions and these can be answered. Can be correlated to the population	Expensive and time consuming	TCS 3.14 Westminster Drive estate TCS 3.4 Coronation Drive estate TCS 3.5/ 3.19/ 3.18 Ballast Bulk Change TCS 4.1 Sutton Village
On street surveys/ interviews	Interviewer can use semi-structured interview question techniques to supplement the fixed questions and in so doing can add value and clarify. Generates valuable qualitative data. Surveyor can use the interview to provide background education/awareness information on lighting Interviewee can ask questions and these can be answered	Samples are unlikely to be representative of population Interviewers need to be trained and understand lighting – often costly Large samples/ populations cannot be cost effectively surveyed Pre- and post-responses cannot be correlated –as sample size is both small and unrepresentative. Statistical significance cannot be calculated Analysis is costly	TCS 4.1 Sutton Village TCS 2.1/ 2.5 Tithebarn Road & Garswood Road Strijp S TCS 9.1 Heiligen strasse & Glaserstrasse TCS 8.6 Stadspark, Aarschot

The BLISS partners carefully designed the engagement for each investment by adapting and combining the four standard engagement methods so that they were 'fit for purpose' for each investment. Each of the methods has strengths and weaknesses. The experiences of the BLISS partners are reflected in the attributes section of the table below. The Technical Case Studies (TCS) provide detailed results.

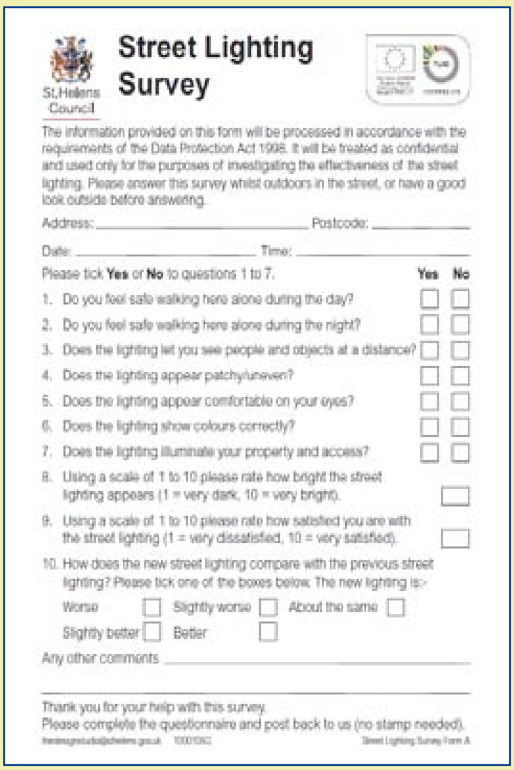
Social media

Eindhoven and Kaiserslautern both used social media to gain input for light settings and light perception research. Eindhoven used. Twitter to gain complaints about light settings. People could tweet their remarks, these were then recoded by the municipal department (Eindhoven) and send to the area manager.
The reply to the residents/users was always via Twitter again.

Eindhoven used Facebook to gather detailed information about light settings. Via the residents could actually join the research (questionnaire). And in the second evaluation Facebook was used to understand the appreciated settings for the light installation. We used this input to work out some new settings and to present these settings to the residents in a local workshop.

Traditional surveys

Partners developed semi structured surveys that could allow the testing of statistical significance and correlation. The schemes used the standard public lighting survey (example below);



St.Helens Council

Street Lighting Survey

The information provided on this form will be processed in accordance with the requirements of the Data Protection Act 1998. It will be treated as confidential and used only for the purposes of investigating the effectiveness of the street lighting. Please answer this survey whilst outdoors in the street, or have a good look outside before answering.

Address: ______________ Postcode: ______________

Date: ______________ Time: ______________

Please tick **Yes** or **No** to questions 1 to 7.

	Yes	No
1. Do you feel safe walking here alone during the day?	☐	☐
2. Do you feel safe walking here alone during the night?	☐	☐
3. Does the lighting let you see people and objects at a distance?	☐	☐
4. Does the lighting appear patchy/uneven?	☐	☐
5. Does the lighting appear comfortable on your eyes?	☐	☐
6. Does the lighting show colours correctly?	☐	☐
7. Does the lighting illuminate your property and access?	☐	☐

8. Using a scale of 1 to 10 please rate how bright the street lighting appears (1 = very dark, 10 = very bright). ☐

9. Using a scale of 1 to 10 please rate how satisfied you are with the street lighting (1 = very dissatisfied, 10 = very satisfied). ☐

10. How does the new street lighting compare with the previous street lighting? Please tick one of the boxes below. The new lighting is:-

Worse ☐ Slightly worse ☐ About the same ☐
Slightly better ☐ Better ☐

Any other comments ______________

Thank you for your help with this survey.
Please complete the questionnaire and post back to us (no stamp needed).

Street Lighting Survey Form A

5.2 Learning from engagement

5.2.1 Acuity Testing

Standard real life acuity tests to understand how well residents can see under different lighting situations are unavailable for public lighting. BLISS developed a suite of tests to understand how users perceived their surroundings in different light. A suite of graphic based tests based on facial recognition, colour, letters, numbers and surface trips was developed for all partners. (TCS 3.4)

VISUAL ACUITY TESTS

Residents and professionals performed different tests. The professionals performed tests developed from the original set of residential group tests to align them with various industry standards. Residents performed tests as shown below.

Facial recognition

Recognise an image of the Queen from the opposite side of the road. The results show the distance at which the Queen could be recognised.

Colour recognition

The residents were asked to identify 4 colours, professionals were asked to identify 12 colours under each luminaire type.
TCS 3.4

Extracts of the Visual Acuity Tests carried out by residents and professionals for each luminaire type.

5.2.2 Crime

One of the purposes behind the BLISS investments has been to explore whether change to lighting affects crime and anti-social behaviour. St. Helens selected the Newtown estate scheme (TCS 3.27) to ascertain whether the levels of crime would be reduced following the implementation of an LED white light scheme.

Post works findings

Part 1 - Initial Thoughts	
Residents' Focus Group	**Professional Focus Group**
"Very bright on pavement. Very safe." **(5700K Cool white 74W LED)**	"Bright, good crime reduction." *Police* **(5700K Cool white 74W LED)**
"Adequate and brightly lit. Felt safe." **(5600K Cool white 58W LED)**	"Bright, can see colours of cars." *Community safety officer* **(5600K Cool White 58W LED)**
"Better than old lights. Feel safe. A lot brighter." **(4000K Neutral white 47W LED)**	"Brighter, more reassuring." *Neighbourhood manager* **(4000K Neutral white 47W LED)**
"Adequate and brightly lit. Felt safe." **(3000K Warm white 71W LED)**	"Reasonable uniformity. Not so cold. Feels safe." *Engineer* **(3000K Warm white 71W LED)**
"Very good vision. Very safe. Best street so far." **(2850K Warm white 60W CPO)**	"Warm, bright. Good. Safe." *Local officer* **(2850K Warm white 60W CPO)**
"Very dull, not bright enough. Feel unsafe." **(2000K Warm white 70W HPS)**	"Adequate, friendly, uniform." *Consultant* **(2000K Warm white 70W HPS)**

Sample of the views of residents and professions to different lighting schemes. (TCS 3.4)

St. Helens Council invited the 440 properties to comment regarding the pre- and post installations. 11% responded to the pre survey and 13% to the post survey. The scheme has achieved 54% reduction in energy consumption and high levels of stakeholder satisfaction. Analysis of crime data records indicate that the crime patterns have changed. Prior to the installation crime had mostly been rowdy and inappropriate behaviour and criminal damage. After the installation there was an increase in thefts of a motor vehicle and theft from a motor vehicle. Perhaps this outcome points towards the benefits of engagement with criminals to understand how lighting affects their behaviour!

Crime Considerations

	Before (3 years) Medium	After (3 years) Medium
Rowdy & inappropriate behaviour	43%	31%
Criminal damage	30%	42%
Theft from a vehicle	19%	7%
Theft of a vehicle	2%	13%
Burglary dwelling	6%	7%

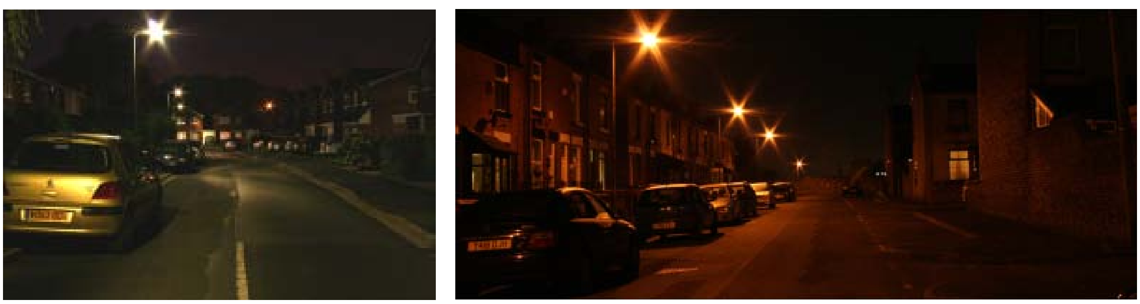
Newtown Area: Crime statistics pre and post installation. (TCS 3.27)

5.2.3 Reduced lighting levels: white or yellow light?

To assess the reactions to reduced lighting levels with regards to colour temperature between conventional SOX/SON (LPS/HPS orange/yellow) light sources and a white light source, quantitative stakeholder research was conducted during Ballast Bulk change schemes (TCS.3.5/3.19/3.18).
Pre and post works postal surveys were conducted with residents in Rainhill; a conversation from the existing 70W HPS to 50W CDO (white light) lamps, and at Marshalls Cross; a direct reduction in wattage from 70W HPS to 50W HPS lamps. 1000 postal surveys were sent to residents and all received the survey before and after the works. The post works questionnaire asked what changes they had noticed as a result of the works.

Conclusion

Almost six in ten respondents were aware that there had been a change in the public lighting and that the new lights improved vision, making the road safer. 84% were satisfied with the new lighting. Coverage, vision and comfort all scored highly, with around three quarters stating that they were satisfied with each element.
81% Of respondents believed that the lighting had made the road safer, and only 7% believed that the lighting would encourage the traffic to go faster.



Simple replacement of ballast- 45% energy savings. St. Helens. (TCS 3.5 / 3.19 / 3.18)

5.2.4 Can improvements to lighting improve business viability?

During the Sutton Village commercial scheme (TCS 4.1), 9 business owners were contacted to understand their aspirations for the lighting. These same businesses were involved post works in evaluating the impacts on their business. This was both through focus groups and by keeping a diary to log any changes in the way their business was working, the ways people were using the spaces and streets along with any general observations. The stakeholders were shown a map of where the new lighting columns would be placed plus photos of the new style lighting in another setting. Street interviews were held post works with users of the areas, to see if opinions differ between the groups.

Before

Pre works findings
Focus group of 9 business owners

Describe the area	Describe the current street lighting	What do you think of the proposed lighting?
"Run down."	"You can't lock your shop up as you can't see. It's terrible."	"Make gangs more visible."
"Every winter you dread it... the florists next door... won't leave until we leave."	"All night long 2 lights are on (inside)... it is the only way that CCTV pick anybody up."	"Lightng does give you confidence."
"No one will come out when it starts getting dark."		"I think you will feel a lot safer walking around Sutton."

After

Post works findings

- 38% noticed a change in the lighting
- 78% believe the new lighting is better
- 68% agree that the area feels safer, however residents are more likely to feel safe than visitors
- 36% were afraid their car would be damaged if parked on one of the local car parks

Comments from business owners and users in Sutton on the new lighting. (TCS4.1)

Conclusion

For the design of lighting schemes this case study illustrated the importance for designers to understand the distinction between designing to reduce crime as compared to designing to reduce the fear of crime. Balancing the call from residents fearful of crime with a need to limit unnecessary lighting is the perennial challenge of both lighting engineers and politicians.

Business owners confirmed that although the new lighting was better, they had seen no reduction in crime, antisocial behaviour or the litter/graffiti. 68% of respondents said the area felt safer - both the business owners and most of the respondents suggested that the improved lighting should have been extended to include the adjacent car park. The luminaires were selected to provide good colour rendition to promote safety and reduce the fear of crime and to allow easy identification of assailants/burglars.

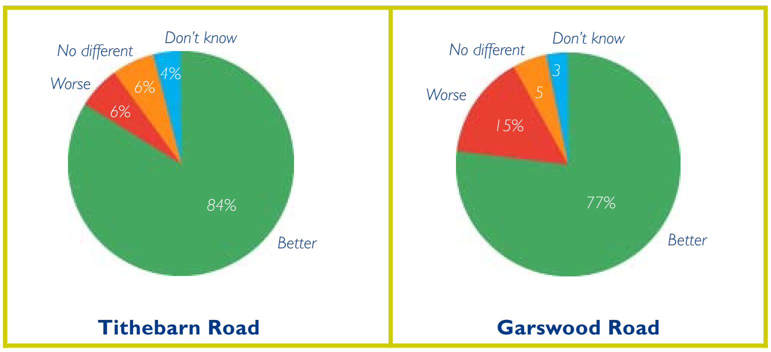
5.2.5 Are road users satisfied?

To evaluate the new LED lighting along a local distributor road (TCS 2.1/2.5), road users were asked to comment regarding their opinions of the new lighting. The challenge here is how to engage with drivers. A survey of 117 on-street and in-home interviews with users of the road after dark as conducted.
The objective was to understand satisfaction levels and to inform a possible new lighting strategy for St. Helens post BLISS. The installation comprised of LED luminaires incorporating varying lighting levels with lumen output reduced to 66% dimming between 24:00 and 06:00. At the time, there was no real experience of this form of SSL on this type of highway. The objectives of engagement were simple and did not warrant the probing of opinions.

Conclusion

Almost six in ten respondents were aware that there had been a change in the public lighting and that the new lights improved vision, making the road safer. 84% were satisfied with the new lighting. Coverage, vision and comfort all scored highly, with around three quarters stating that they were satisfied with each element. 81% of respondents believed that the lighting had made the road safer, and only 7% believed that the new lighting would encourage the traffic to go faster.

Is the new street lighting better or worse? (%)



New LED lighting welcomed by road users - 33% energy saving.
(TCS 2.1/2.5)

New LED Lighting welcomed by road users - 33% energy saving. St. Helens. (TCS 2.1 / 2.5)

5.2.6 What do residents prefer?

BLISS partners recognise that the views of stakeholders varies and in particular there may be differences between professionals and residents. This was a study (TCS 3.4) to understand the differences between residents' preferences and those of the lighting engineers'. One LED is certainly not like another.
The colour "temperature" of lights can be different and this can provoke very different moods. Pre and post surveys of residents through focus group meetings and a walk through the site were undertaken. A professionals' group was taken on a walk through the site. All participants were asked to score their preferences for different colour temperatures from a range of different light sources (HPS, CPO and LED). Visual acuity tests were undertaken based on the ability to see a variety of colours, shapes and charts under the differing lighting conditions. The tests recorded:

- Initial thoughts
- Facial recognition
- Colour recognition
- Text recognition
- Scoring – Preference of colour temperature

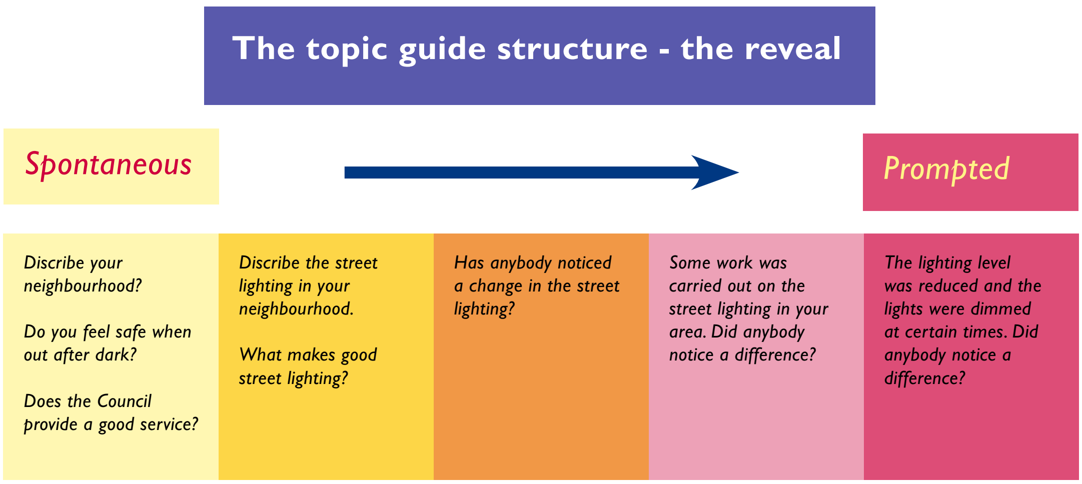
Conclusion

The results show that the opinion of residents and professionals differs in terms of light sources. However, both groups preferred a similar warm white colour temperature, with the residents preferring the CPO lamps, which produced a warmer white. The professionals preferred LED luminaires in a warm white colour temperature. The HPS lamp was voted second best by the professionals, which contradicts the opinion of the residents who believe it to be the worst. Residents generally appeared to be more concerned about the appearance and safety of where they live, and many saw the lighting as a vital part of this security.

5.2.7 Differences in residents perception – statistically significant or not?

A ballast change scheme (TCS 3.5, 3.19, 3.18) was undertaken to reduce energy consumption. This had the potential to be retro fitted at minimal costs.
A postal survey consultation was undertaken to gauge citizens' perceptions of changing 70W SON to 50W SON (reducing wattage but same colour) with reduced lumen output and electronic ballast. 600 questionnaires were distributed to residents who were not informed about the proposed works. Half of the residents received the pre works survey and the other half of the residents received the post works survey.

The objective was to identify if any differences in the responses were statistically significant. The survey identified that residents feeling 'very unsafe' increased from 10% before to 21% after works. Due to this deterioration in the residents' perception of safety in the area, the survey was followed up by establishing a residents' focus group to investigate the reasons for this.
8 Residents attended for a 90 minute discussion using a "topic guide" to progressively open up the discussion (see diagram below).



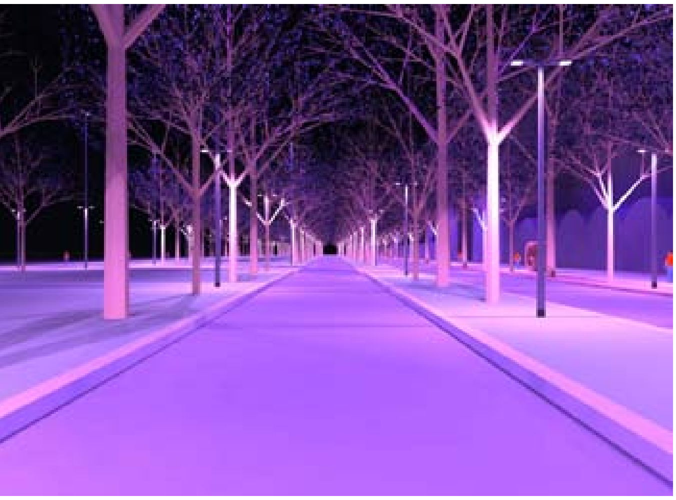
Conclusion

6 of the 8 residents had noticed a difference, but neither supported nor agreed with energy reduction or the cost benefits of dimming. Residents required significant reassurance that close monitoring of crime would be undertaken and that if necessary, dimming would be cancelled. The example demonstrates that the environmental and economic design drivers for politicians and designers are not shared by some residents, whose priority is high levels of illumination, almost regardless of the cost. They questioned.. "what is in it for us"

5.2.8 Do citizens like coloured lighting?

Eindhoven has high ambitions relating to sustainability, the adoption of low-energy technologies and understanding what lighting stakeholders will accept as comfortable and attractive (aesthetically pleasing and culturally enriching). It is also about creating a strong sense of place in this major regeneration project. The lighting installation along the Torenallee is a broad, spacious area with a one way road, sidewalks, bicycle path with grass and trees in between. The luminaires use two types of colour LED modules 50% of the modules (16) with RGB and Neutral White LED and 50% with RGB and Cool White LEDs. The luminaires are individually dimmable in 255 steps from 0 to 100% lumen output using the DMX technique. The Design concept was to provide at least six different lighting scenes.

Torenallee, Strijp-S Eindhoven, with a sample of the variety of coloured lighting available using RGB LEDs. (TCS 6.6)



The Festive scene

The Cosy dinner scene

The Morning scene

The evaluation of the Torenallee lighting installation (TCS 6.4) explored these six colour designs with residents to understand their colour awareness and experiences of the lighting;

The "festive scene" was designed to be cheerful and give people the feeling of pleasure and happiness. Residents considered "the scene" to be calm, monotonous and a bit boring. They saw it as spacious but sharp, sad and lonely. Few thought it safe, dynamic or having ambience or identity. Residents thought of it as a late night scene.

The "cosy dinner scene" was designed to be versatile, lively, warm, soft, snug and exciting. Residents felt confident, relaxed and comfortable in this scene. They felt safe in this scene and that it contributes to the ambience and identity of the Strijp-S environment. Most people indicated it as an evening scene.

The "morning scene" was considered by residents to be stimulating, cold, sharp, hard and especially bright. They did not find it comfortable or relaxing but rather irritating and tense. The scene has a clear ambience and identity. Residents indicated that this light is a wake-up call for in the morning.

The "moonlight scene" is a scene with a low level of light intensity. Residents considered it to be versatile and lively but also restful. Residents also described it as spacious, bright, modest, warm and a bit detached. They considered the light to be safe, relaxing, pleasant and calming and associated it with the (early) evening.

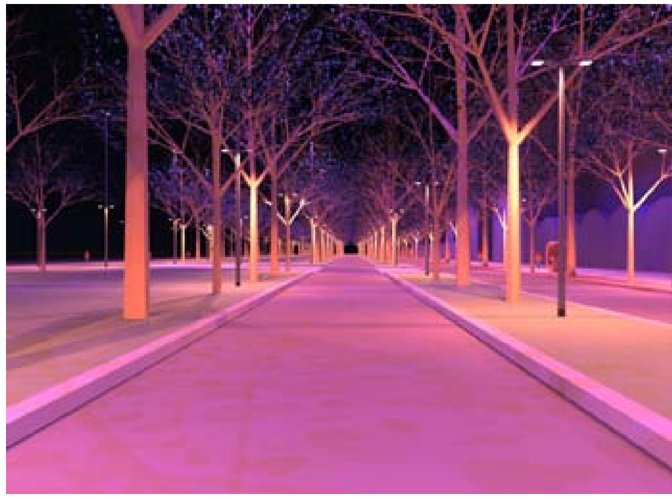
The "weekend scene" was experienced as versatile, lively, restful, comfortable, warm and soft but dark. Most residents consider that it belongs to the evening. Quotes indicated the light to be pleasant, contributing to the ambience of the local environment.

The "budget scene" consisted of only white light, the standard public lighting. This light was considered as monotonous, spacious, very bright, cold, hard and sharp. Residents expressed feelings of loneliness and that although it was clear and bright it was not exciting. Views differed on the different times of day they associated with the light.

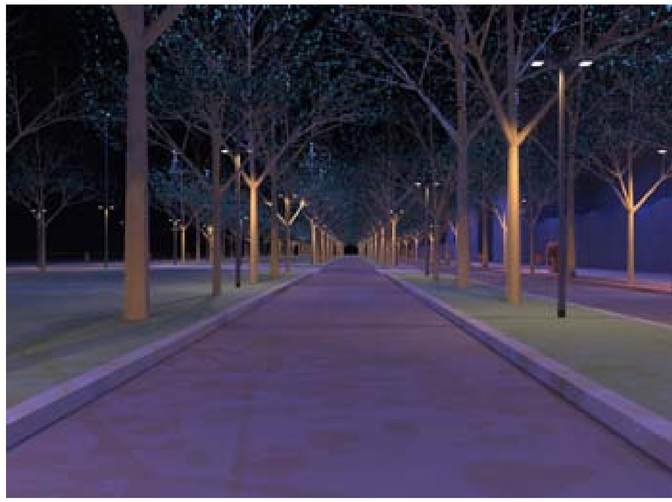
5.3 Recommendations

Municipalities should:

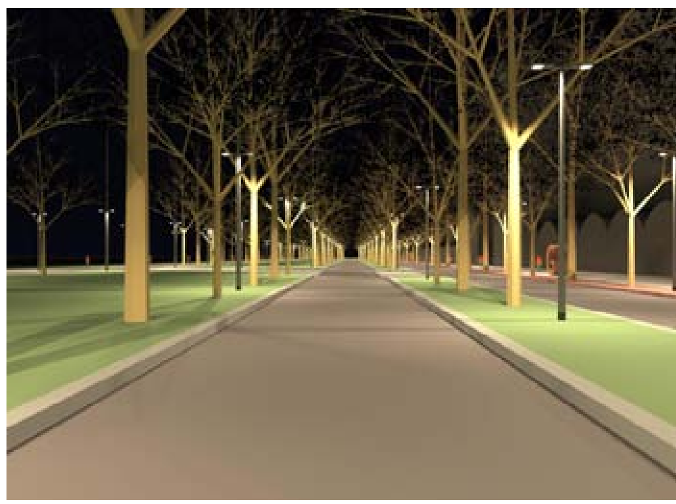
- Recognise the value of engaging with stakeholders in public lighting.
- Learn from the experiences and lessons of the BLISS project.
- Tailor engagement and consultation tools for different stakeholder groups (e.g. using Internet, Facebook, focus groups etc.).
- Use the engagement tools and techniques developed in the BLISS project.
- Make sure they understand the differences of opinions and views between stakeholders and how the municipality will balance opinions and views.
- Expect the unexpected - consultation does not always produce the expected results!
- Be prepared to keep on learning from engagement.
- Be prepared to change specifications and designs following consultation.



The Moonlight scene



The Weekend scene



The Budget scene

Norman Avenue, St. Helens. (TCS 3.4)

6. Glossary

BLISS Better Lighting in Sustainable Streets
BS British Standard
CCT Correlated Colour Temperature
CENELEC European Committee for Electrotechnical Standardization
CEN Comité Européen de Normalisation
CMS Central Management System
CO2 Carbon Dioxide
CPO Cosmopolis
CRI/ Ra Colour Rendering Index
DNO Distribution Network Operator
E Illuminance
E1,2,3,4 Environmental zone classification
Eave Average illuminance
Emin Minimum maintained illuminance
EAC Estimated Annual Consumption
EN European Standard
ETSI European Telecommunications Standards Institute
FCO Full cut-off
G Class Luminous intensity classification
HPS High Pressure Sodium
I Light Intensity
ILP Institution of Lighting Professionals
IMD Index of Multiple Deprivation
K Kelvin
kWh Kilowatt Hour
L Luminance
LED Light Emitting Diode
lm/W Lumens per watt
LPS Low Pressure Sodium
LSOA Lower Super Output Area
lx Lux
ONS Office for National Statistics
PNC Private Network Cable
RGB Red Green Blue (LED's)
S Class Subsidiary road class
TCS Technical Case Study
TCO Total Cost of Ownership
TVO Total Value of Ownership
ULOR Upward Light Output Ratio
UMS Unmetered Supply
Uo Overall uniformity
UV Ultra Violet
W Watts
WEEE Waste Electrical and Electronic Equipment

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7. Colophon

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