EUROPEAN COMMISSION
Directorate-General for Communications Networks, Content and Technology

Lighting the Cities

Accelerating the Deployment of Innovative Lighting in European Cities

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PREFACE

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The European Commission would like to thank all the members of the EU Task Force on Solid State Lighting for Cities (ref. to Annex), as well as Mr Martin Goodwin, for their contributions to this paper.

Contents

This report is aimed at **European Cities** and their **indoor and outdoor lighting infrastructures**.

It is directed towards those cities who might be considering their first SSL deployments and to those that have some experience but would benefit from more information.

1. INTRODUCTION

European municipalities are increasingly looking to improve efficiencies and reduce costs for providing services to their citizens, especially so in the times of austerity now facing Europe.Public lighting represents a significant share of their total electricitycosts, accounting for up to 60% of that budget.

The adoption and deployment of new technologies, such as Solid State Lighting (SSL), offer significant opportunities for meeting this challenge, and this philosophy is embodied in the concept of **Smart Cities**[1], increasingly being adopted across Europe.

SSL is based on light-emitting diodes (LED) and organic LEDs (OLEDs). It is the most innovative lighting technology emerging on the market. Itoffers high quality light and visual performance, while providing substantial cost saving opportunities, reducing light pollution in cities and driving innovation in the lighting and construction sectors.When SSL is combined with intelligent light management systems, it can save up to***80% energy consumption and money*** compared to current lighting technologies.

The European Union has set itself an ambitious target: by 2020, to reduce energy used for general lighting by at least 20%.

This target will be achieved through the massive deployment of Solid State Lighting solutions in Europe.

Intelligent SSL systems form an essential part of the broader Smart Cities initiative of the European Commission, offering in addition to these substantial energy savings, the further benefits of intelligent control, networked communications, and establishing a fully integrated control infrastructure, allowing, for example, direct interaction with the city power management systems.

Several EU cities have already deployed SSL and experienced its benefits over traditional lighting technologies. They report among other things increased lighting efficiency, energy savings up to 70% to 80% and consequent substantial cost savings and reduced maintenance costs. SSL is already mature enough to be justified by a sound business case based upon total cost of ownership. In addition, it enables creative lighting deployments to enhance cultural aesthetics and promote citizen safety and well-being.

- There are over 90 million traditional streetlights in Europe, with over 75% of the installations being more than 25 years old.
- There are massive opportunities for energy savings from the widespread deployment of SSL technology in EU cities.

This report is aimed at European Cities and their indoor and outdoor lighting infrastructures.It presents the findings of a Task Force for Cities[2]that was established by the European Commission with the aim of delivering a roadmap for achieving wider deployment and major rollout of new lighting technologies based on Solid State Lighting for cities throughout Europe. The report is directed towards those cities who might be considering their first SSL deployments and to those that have some experience but would benefit from more information.

[1] http://ec.europa.eu/energy/technology/initiatives/smart_cities_en.htm

[2] The Members of this Task Force are provided at the end of this report.

It is also anticipated that this report could be of value for informing local and national government organisations, as well as for the wider SSL community.

The report aims to provide clear guidance on how best to roll out SSL, covering:

- Why consider SSL technology now
- How to make a business case and secure funding
- How to specify and procure SSL equipment
- How to secure social acceptance of SSL technologies

Recommendations are given on how a city could initiate an SSL deployment, covering the preparation of an urban lighting strategy, development of the business case through consideration of immediate cost savings and longer term total cost of ownership analysis, and the vital activity of engaging with local businesses and citizens to ensure the best prospects for acceptance and success.

The practical issues of component selection and procurement are provided, with particular emphasis on the practicalities of securing financial support and training the city procurers on the key issues relating to specifying this new lighting technology.

The report discusses how experiences of SSL deployments can be leveraged to maximize benefit within Europe, through the communication of results and lessons learnt, and through the formation of municipal associations and communities of practice.

The deployment of energy saving SSL coupled with microelectronic sensors for detecting environmental conditions, presence and light output could be the first steps in the realisation of smart cities. Such solutions should be interlinked and dynamically interact with other smart city systems, such as communication and smart sensor networks, energy, facility, mobility and street lighting management systems as well as PV to provide dynamically adapted optimal lighting conditions at minimum energy consumption and ultimately to contribute to zero-energy buildings and neighbourhoods.

2. WHY MOVE NOW TO INTELLIGENT, CITIZEN-CENTRIC SSL?

Public lighting accounts for up to 50-60% of typical municipality electricity costs, with street lighting being the largest user. In street lighting SSL solutions offer energy savings of up to 52% over mercury vapour high-intensity discharge lamps and 26% over sodium fixtures.

The much longer lifetime of SSL also reduces maintenance costs that, when combined with energy savings, mean that municipalities can recoup the costs of a basic non-networked LED-based street lighting installation in four to six years[3]. However, in addition to

Factors driving the adoption of Intelligent SSL in cities

- Need to reduce operational costs for service provision
- Significant (up to 80%) energy savings & extended luminaire lifetimes
- Better light quality and visibility and less light pollution
- Greater lighting design creativity and functionality
- Improved street safety and security

[3] It is predicted that with an uptake of LED technology, the prices will be more or less the same as standard lights in four years' time. Source "StreetSMART" in Traffic Technology Today, January 2010, http://viewer.zmags.com/publication/6e26c868 - /6e26c868/1

cost cutting, energy-savings and low maintenance, SSL also offers other benefits in terms of improved customer service resulting from the superior controllability of light colour, intensity (dimming[4]), and direction. In outdoor lighting, for example, SSL offers better visibility and less light pollution due to high uniformity of coverage, colour quality and tuning. A recent survey[5] showed that for public lighting citizens preferred the white light provided by SSL to the colour of conventional street lighting, and that SSL offered greater subjective visibility and public safety. A well-lit city is a safe and comfortable city, and the design creativity offered by SSL contributes to enhancing city environments.

When smart control is added to SSL for dynamically changing lighting levels in response to specific needs, the total system energy saving can reach up to 80% and deliver a much wider range of social benefits. Such 'intelligent' lighting allows communication between lamps and provides remote access, resulting in a total system that includes dimmable luminaires, advanced lighting control and individual monitoring of luminaires. A key factor here will be the control system and its interaction with the other networks for a truly integrated light and energy management approach. Networked street lighting has been shown to reduce energy use by up to 40% while improving citizen safety, extending lifetimes, decreasing maintenance costs, and providing better lighting performance[6]. Similarly, intelligent SSL can bring potential benefits to road users and road safety & security (LED lamps can strobe or change colour to signal an emergency situation). Also in schools, an SSL system combining colour and intensity has been shown to dramatically improve student performance[7]. Finally, the significant contribution offered for the lighting aesthetics and its use for enhancing a city's cultural identity should not be underestimated. A fine example of this is the application of LED illumination to the Brussels Town Hall[8].

Why move to SSL now

- SSL is already a quite mature technology and high-quality luminaires are commercially available and at attractive costs
- Within a digital lighting system, LEDs are the most efficient light source available, offering long lifetimes (in excess of 50.000 hours) and savings of up to 80% over conventional light sources
- SSL deployment experience exists - many EU cities are gradually adopting intelligent SSL lighting solutions
- SSL deployment provides opportunities for stimulating local economy through engaging with local businesses

Consequently, analysis of the potential value to municipalities of switching to SSL is not limited solely to a cost-benefit analysis offsetting higher purchasing costs against the significant savings on energy and improved lifetimes. Although the positive result of such an analysis is fundamental to each decision to switch to SSL, there are other aspects to consider arising from the increased functionality offered by intelligent SSLlighting.

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4 LED lifespans increase when the drive current is reduced, making them ideal for smart control

5 LIGHTSAVERS programme. "Lighting the clean revolution", http://thecleanrevolution.org/publications/lighting-the-clean-revolution-the-rise-of-leds-and-what-it-means-for-cities

6 E-Street www.e-streetlight.com) predicts an annual saving of 64% in streetlight energy consumption from introducing intelligent street lighting in Europe.

7 See, for example, Barkmann et al (2009), 'Effectiveness of dynamic lighting in Hamburg schools', accessed www.ubp-herten.de/UKE-Ergebnisbericht_Feldstudie.pdf

8 http://www.luciassociation.org/new-sound-and-light-show-in-brussels-belgium.html

Why move to SSL NOW?

The benefits of adopting SSL technology are manifest, but the question remains as to why municipalities should embark on this path now, particularly when service provision budgets are tight and new investments closely scrutinised? In essence, it is because this is a technology whose time has come - the technology has achieved the necessary degree of maturity to justify serious consideration. High quality luminaires are commercially available and at attractive costs. Experience is steadily increasing through widespread deployment trials across Europe, resulting in a solid body of best practice for design, financing, procurement and deployment. Combine this with a growing regulatory drive for energy efficiency (see next section), and a compelling case for deploying SSL emerges.

The main barriers to deployment of this attractive technology are:

- There is limited awareness amongst many municipal lighting departments and luminaire designers of the substantial benefits offered by SSL;
- The up-front investment costs for SSL are higher than for conventional lighting, requiring a consideration of total cost of ownership to determine the full potential economic benefits;
- There is a great variability in product quality and in the reliability of information provided by SSL suppliers and a lack of shared data information in tested SSL products.

Overcoming these barriers is discussed in section 3.

A favourable European policycontext

The current EU policy context is particularly favourable for the deployment of high quality LED lighting in outdoor and indoor installations. The Green Paper 'Lighting the future'[9] laid down the basis for the widespread deployment of high quality SSL in Europe. Lighting installation (mainly in the non-residential sector) is one of the main elements for calculating the energy performance of the buildings, as required by the EU directive on Energy Performance of Buildings[10] (EPBD). The recent Energy Efficiency Directive[11] asks Member States to renew central government buildings in agreement with the minimum energy performance requirements of EPBD, and encourages the application of energy management systems. It also asks that authorities purchase only products, services and buildings with high ratings for energy performance, consistent with the Energy Labelling[12] and Ecodesign[13] directives, which also strongly support the transition to high quality LED lighting in outdoor and indoor residential installations.

The new EC 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 LEDs). The gradual phase out of inefficient directional lamps is expected by 2016, when only class A+ and A++ will remain so that the superior energy efficiency of LEDs can be highlighted. The quality of the lamps will be assured by the new Ecodesign regulation for directional lamps and LEDs completing and complementing the previous regulations for non-directional and professional lamps.

Finally, Green Public Procurement (GPP)[14] criteria exist forindoor and street lighting and for traffic

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[9] COM(2011) 889 final of 15 December 2011

[10] DIR 2010/31/EU

[11] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012

[12] Regulation 874/2012/EU of 12 July 2012

[13] Regulation 1194/2012 of 12 December 2012. Regarding LEDs, it completes and complements the Regulations 245/2009/EC and 244/2009/EC.

[14] Green Public Procurement (GPP) is voluntary scheme at EU level. It is a process whereby public authorities seek to procure goods, services and works which have a reduced environmental impact throughout their life cycle. See COM(2008) 400.

signals. They provide state-of-the-art specifications for lighting products and services with a reduced environmental impact throughout their life cyclethat Member States may wish to consider when procuring such goods.

Examples of pioneering European cities

The uptake of any new technology needs time and effort to raise the awareness of users to the benefits of a new product compared to the traditional ones. The need to generate such evidence for lighting product users (citizen lighting designers, electrical installers, building constructors, etc.) has persuaded many European public administrations to launch pilot actions aimed at establishing the performance and reliability of SSL installations, and assessing their social benefits.

Representative European experiences of SSL deployments are illustrated by the following Case Study summaries:

Birmingham City (UK)[15]

This is the largest municipal LED deployment in Europe so far comprising 90,000 street lights.The expected energy savings are of 50% leading to a £2m reduction in annual running costs. The incurred higher up-front costs for providing smart controls are fully offset through consequent cost savings associated with lower energy consumption, maintenance costs, and luminaire replacement.

SSL in Birmingham City

- 90,000 street lights
- 50% expected energy savings leading to a £2m reduction in annual running costs
- Managed 100,000 hours operation lifetime
- Maintenance savings were a key factor in selecting SSL
- The whole operation is financed through a 25-year Private Finance Initiative contract.

An effective public lighting strategy has been implemented incorporating (i) smart networked controls allowing dawn and dusk trimming of lighting levels and dynamic lighting output management for lumen depreciation; and, (ii) a real-time monitoring system that allows the collection of performance data with consequent efficiency in lighting control.It will be possible to vary the light level of individual lighting units according to its recorded needs, and so achieve a significant reduction in energy consumption.

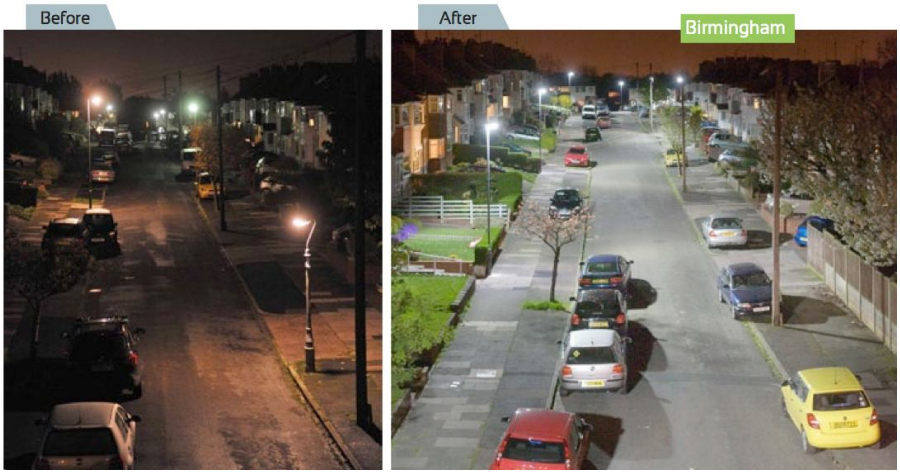

Figure 1: The impact of LED deployment in Birmingham

15 http://birminghamnewsroom.com/2012/07/city-is-shining-thanks-to-10000-eco-friendly-leds/

Lyon (France)[16]

Lyon is a major cultural city that has embraced SSL lighting for illuminating its historical urban environment. Lyon provides a good illustration of how SSL can meet varying illumination requirements, with lighting designs selected to match the different areas of the city and their respective functionalities. This innovative approach makes use of the great flexibility of LEDs to provide distinct lighting identities across the city. In addition, Lyon has adapted the design of lighting at pedestrian crossings, bus stops, etc. to aid people with visual and mobility disabilities.

SSL in Lyon

- In the refurbished Guillotière Bridge, achieving 50% energy savings
- In Place Bellecours, saving 130,000kWh per year
- In the Passerelle St Vincent pedestrian bridge, together with proximity sensors to dim light levels to 10% when unused
- Host to the annual Festival of Arts, using LED fixtures designed by local light artists - LED fixtures use a tenth of energy and last 20 times longer

Figure 2: Lyon city centre[17]*(© City of Lyon)*

Leipzig (Germany)[18]

Leipzig is the first city to deploy SSL in Germany. The current deployment strategy in the city centre is to provide Intelligent Urban Lighting with major emphasis on the environmental, economic and social aspects of lighting. The adopted approach uses a mixture of retrofitted historic luminaires for heritage lighting and new fixtures for road lighting. The deployment of SSL demonstrates how lighting quality can be improved without undermining the city's cultural and social identity based on its history and artistic heritage. Adopting an integrated approach of SSL within the historical lanterns of Leipzig achieved lighting in

SSL in Leipzig

- Retrofitting historical lanterns saves 74% energy
- SSL with centralised modular control system achieves an overall energy saving of 50%
- Prize winning city for street lighting energy efficiency
- €645k installation costs with 7-10 year payback period
- Supported by 40% federal grant

16 http://www.luciassociation.org/lyon.html

17 Courtesy PLUS project (http://www.luciassociation.org/plus) and LUCI Association

18 http://www.luciassociation.org/leipzig-germany.html

harmony with the old city, whilst still providing significant energy savings.

Figure 3: Leipzig city centre

Eindhoven (The Netherlands)[19]

Eindhoven uses special lighting effects for many outdoor and public objects, including buildings, parks, and art works, thereby earning the accolade of 'City of Light'. Eindhoven has installed sensor activated lighting systems that dim the light levels in the absence of cyclists or pedestrians, thus reducing costs. The city is closely linked to the major LED supplier Philips, whose headquarters are based locally, and so hosts many SSL demonstration installations.

SSL in Eindhoven

- In sporting areas, providing high light levels without the glare or light spillage associated with conventional lighting
- In the Catharinaplein square: it is lit with an innovative SSL design using 'floating' luminaires with minimal lamp posts, to provide an atmospheric feel and create additional public space for citizens
- As part of the annual GLOW festival, a recent art installation used 30,000 coloured LEDs to illuminate a 25 metre high dome in the style of the Italian Renaissance

An innovative feature of the SSL deployment in Eindhoven has been the use of colour to provide safety information and to reduce environmental impact. Coloured lights have been installed in the pavements as auxiliary safety indicators to better highlight pedestrian and cyclist crossings in the city, and low intensity green lighting has been deployed on rural cycle paths to improve visibility and minimise impact on the local fauna.

[19] http://www.luciassociation.org/eindhoven-the-netherlands.html

Figure 4: Road Lighting in Eindhoven[20] (© City of Eindhoven)

Other examples of Citiespioneering SSL

Many other European cities are actually deploying intelligent SSL lighting or are experiencing its use in pilot implementations. Examples include Amsterdam, Budapest, Copenhagen, Dresden, Ghent,Gothenburg, Nice, Stockholm, Tallinn, Tilburg, etc.

In support of SSL deployments, the European Commission is operating several pilot actions through its Framework programme for Competitiveness and Innovation (CIP). These involve LED lighting for indoor and outdoor lighting in cities within the programme PSP[21] (LED4ART[22], ILLUMINATE[23], LITES[24]).Beyond Europe, several other countries are also investigating the benefits of SSL though state supported R&D initiatives and pilot projects. Through these a better understanding of the practicalities of municipal deployments is emerging.

The LightSavers program[25] collated case study information from a consortium of 12 major cities across four continents, through field-testing of 27 LED products in a series of 15 trials.

3. PREPARING THE TRANSITION TO SSL

Committing to Change – Adopting an urban lighting strategy

The SSL deployment strategy must be based on a clear understanding of the lighting requirements and of any shortcomings associated with the existing deployment.With a clear appreciation of what the new SSL deployment must provide, both in the short term and within a longer term, the lighting strategy for the particular municipal deployment is to develop a detailed technical plan and its associated business case(s).

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[20] Courtesy PLUS project (http://www.luciassociation.org/plus) and LUCI Association

[21] http://www.cip4led.eu/

[22] http://www.led4art.eu/

[23] http://www.illuminateproject.eu/

[24] http://www.lites-project.eu/

[25] 'Lighting The Clean Revolution', June 2012, http://thecleanrevolution.org/publications/lighting-the-clean-revolution-the-rise-of-leds-and-what-it-means-for-cities

ESOLi has produced an illustrative guide of Best Practice[26] based on SSL deployments across Europe that summarises experiences across a range of municipal lighting requirements, and offers guidance to new users. A broader perspective of adopting SSL is provided by en.lighten[27], an international organisation sponsored by the UN:a detailed toolkit was produced, "Achieving the Global Transition to Energy Efficient Lighting"[28], which provides guidance for countries considering making the transition to SSL.

The Swedish Environmental Management Council has established Procurement Criteria for Lighting Productsbased on *life-cycle*

Basic steps for preparing a citizen-centric lighting strategy

- ***Assessment***: What is the extent and capabilities of the existing lighting system, and are there major shortcomings?
- ***Vision***:Where do you want to go with your lighting system? Are there specific targets, both the quantifiable and those less tangible?
- ***Zoning***: Do the lighting requirements vary within the different zones of the planned deployment?
- ***Changes***: What specifically needs to be implemented to move from your current system to the desired lighting vision?
- ***Planning***: Develop a five- or ten-year deployment strategic planning that will allow these changes to be implemented. Consider additional environmental issues, such as recycling of old luminaires.
- ***Stakeholder***

Assessing the Status Quo – Planning & building the business case

Develop the economic case

Assessing the full economic value of an SSL project and then securing the necessary capital investment, requires the application of standard analysis techniques. These tools have been widely used in the energy efficiency industry, and can be readily applied to SSL. They are based on the concept of *Total Cost of Ownership* (TCO), also known as "full*life-cycle cost* (LCC) analysis", and provide a more realistic assessment of the long-term economic value to the owner of the SSL system. An example of the LCC approach to green public procurement of indoor and outdoor lighting is detailed in the Swedish Environmental Management Council's Procurement Criteria for Lighting Products[29], which also has links to a lighting calculation tool.LCC must be complemented by the impact on maintenance costs, the possible relocation of luminaires and the training of personnel.

Key steps for planning SSL deployments

- Develop the economic case to justify the investment, including return on investment and life cycle costing analysis
- Identify and engage with the key stakeholders, including citizens
- Establish

This analysis should also include consideration of the financial impact of changes in maintenance schedules,

Any business case for SSL should include analysis of societal benefits

- Improved security for citizens
- Cultural or aesthetic enhancements
- Improvements in workplace – learning – healthcare environments
- Changed citizen perceptions to their living environment
- Attracting more tourists for the city and visitors for local commerce

[26] http://www.esoli.org/images/stories/Download/ESOLi_Best_practice_catalogue_EN_120426.pdf
[27] http://www.enlighten-initiative.org/
[28] http://www.enlighten-initiative.org/portal/CountrySupport/Toolkit/tabid/790827/Default.aspx
[29] http://www.msr.se/en/green_procurement/criteria/Office/Lighting-products/ and http://www.msr.se/en/green_procurement/criteria/Street-and-property/Outdoor-lighting/

possible relocation or replacement of luminaires (for optimising lighting conditions), and any staff training required, so addressing the full picture. A practical example of this is the Birmingham City deployment mentioned earlier[30].

An appreciation of the range of SSL lighting equipment and its performance capabilities can be obtained by consulting supplier information. However, it is best to consult databases assembled by municipalities themselves for accessing impartial test results. For example, EANDIS, the Belgium energy distributor that coordinates SSL for many Flemish municipalities, has accumulated test results on a wide range of components and this database is accessible online[31].

Engaging with stakeholders, actively involving citizens and promoting local innovation

For any planned deployment of SSL in municipalities, engagement with stakeholders and citizensis essential for securing social acceptance of SSL from local residents and for providing new business opportunities at the local level.Such engagementshould be a key factor at all stages of the process right from the initial planning stage through to post-deployment system evaluations.

Local economic development policies would profit from a better understanding by cities of the existing contribution companies can make in the lighting sector and their related growth potential. Cities could then better support the local lighting sector to generate more jobs. There are also many benefits for cities of working more closely particularly with their Universities and higher education sector to establish local courses and expertise in lighting design and engineering.

Stakeholders to engage with in SSL deployment

- Local citizens, shopkeepers
- Municipal departments
- (Lighting) Industry and local research organisations
- Energy companies
- Trade associations

Specifically, engagementcan be foreseen in the following manner:

- **Planning phase:** Early engagement with all stakeholders through local consultations atthe definition phase of the overall lighting concept. This will help mitigate natural conservatism that might otherwise result in unwarranted concerns about 'new technology'[32].Early involvement of local industry and local research actors will help contribute to best planning and to technological innovation. This might also require general information/education measures to provide a better understanding of SSL and so improve awareness and ensure a wider appreciation of the benefits of SSL. There may also be valuable opportunities for engaging with local lighting companies to promote new business possibilities that could accompany a planned SSL deployment.

- **Deployment phase**: Supplying stakeholders with clear information on the planned timescales and actual achieved progress in order to ensure positive engagement, and likely to increase the community acceptance of any disruption or delays encountered during deployment.

- **Evaluation phase**:Seeking feedback from thestakeholders on the outcome of a deployment, as well as the overall process itself. This includes disseminating information on the effectiveness of the new SSL system in terms of lighting quality, energy efficiency and impact on society or local business.

[30] http://www.luciassociation.org/images/stories/PDF/plus%20mainstream%20guide.pdf

[31] Reference for EANDIS database (requested, but no response yet)

[32] Evaluation of previous SSL case studies has not indicated this as having been a significant issue.

4. Measures through which such a dialogue with stakeholders could be initiated and sustained by the municipality include forum meetings, representation on planning committees, articles in the local press and on community web sites, and awareness surveys.MAKING THE TRANSITION

Scoping the market

A wide range of commercial SSL products is now available and their number is increasing steadily. The selection of luminaires and other associated equipment requires a detailed evaluation of the specific lighting needs of the proposed deployment. Detailed assessments of the performance and availability of LED lighting equipment specifically for both street and office lighting deployments have been performed as part of EU projects related to the Eco-design directive on energy using products (EuP). Reports on these assessments are available for download from the EUP4LIGHT website[33].

Other comparable databases include the LED Lamp & Fixture Locators[34] and the US Department of Energy (DoE)EnergyStar Certified Lighting Subcomponent Database[35]. More generally, the DoE has also produced a reference document 'LED Fixture Datasheet Checklist'[36] to guide users through the process of component specifications, and has defined the requirements[37] for compliant SSL products used for general illumination.

Major steps for transitioning to an SSL system

- Selecting the SSL system and supplier
- Securing the finance to cover initial investments
- Procuring and installing the SSL system
- Establishing revised maintenance procedures
- Monitoring the transition and periodically updating or revising strategy plan as necessary
- Establishing or subscribing to a database of test results
- Establishing or joining a network of support, e.g. Lighting Urban Community International (LUCI)

Securing financing

A major challenge for the uptake of SSL in Cities is the high initial investment costs for such applications, in comparison to conventional technologies. Even if an SSL project can pay this back through the achieved energy savings, the high initial investment cost may still present a barrier to implementation. If municipal deployment of SSL is to be accelerated, alternative models of financing must be considered.

The majority of public funding sources available for lighting projects are managed at the national level (although some come from the EU and other foreign donors), and funding conditions differ in each Member State. In general, the funds are not solely for SSL, but are usually provided in association with environmental and energy saving issues.

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33 www.EUP4LIGHT.net

34 http://www.ledfixturelocator.com/ and http://www.ledlamplocator.com/

35 http://www.energystar.gov/index.cfm?c=lighting.pr_lighting_subcomponents

36 http://www.energystar.gov/ia/partners/downloads/meetings/lighting/2009/SSL-Overview_Questions_to_ask_your_LED_Fixture_provider-Riesebosch.pdf?5a6f-93bf

37 http://www.energystar.gov/index.cfm?c=archives.luminaires

At the European level, the European Energy Efficiency Fund[38] (EEEF) targets energy efficiency and renewable energy investments in Member States. The final beneficiaries of EEEF are local and regional authorities, as well as public and private entities acting on their behalf. EEEF offers two types of investments:

1. Direct Investments in energy efficiency and renewable energy projects, typically in the range of €5m to €25m. Investment instruments include senior debt, mezzanine instruments, leasing structures, and forfeiting loans.

2. Investments into Financial Institutions, including investments in local commercial banks, leasing companies and others. The financial institutions only lend to the beneficiaries of the Fund that meet the eligibility criteria for financing energy efficiency and/or renewable energy projects.

Another source of European funding is the ELENA program[39] initiated by the European Investment Bank. Information on the funding sources available in a range of European countries has been collected by the ESOLi project[40].

Finance Models

Public-private partnership models for supporting energy services may be a viable option for saving energy and maintenance costs, whilst at the same time guaranteeing high quality lighting systems. Usually, this means financing and operating procedures for providing specific energy services to the owners of the street lighting systems, but may also include cost effective delivery of electricity to the system owner. There are also energy service models that include provisions for utilisation of renewable energy, replacement of existing components & systems, energy metering and billing, Life Cycle Cost Assessment, and interfaces with other customer services.

The main distinguishing feature of most energy services is that the energy service company (ESCO)[41] bears the risk of the lighting and installation management with regard to energy. With this responsibility comes the chance to make profit, once the intended improvement in efficiency has been achieved.

Energy Service Models

There are three basic models for the provision of the energy service:

- **Lighting Contracting** – a pure service model, where the lighting system ownership remains with the public authority. It is the simplest and the most widely used model.
- **Light Supply Contracting** – a complete transfer of the system to a private company. The contractor takes over the full responsibility for the lighting system, including the planning and construction of lighting system, the financing and operation of system, the invoicing of the finished end product, and the purchase of electricity. This latter feature might be attractive if the contractor is a utility with access to advantageous electricity prices. However, it could be less attractive to a municipality, as they would be bound to the contractor over the full contract period.

Given the rapid SSL technology evolution, energy saving contracts should include specific provisions to ensure that installed LED sources are regularly replaced by better performing and more energy efficient ones.

[38] http://www.eeef.eu/

[39] http://www.eib.org/products/elena/index

[40] http://www.esoli.org/

[41] **Energy Service Company (ESCO)** delivers energy services in a user's facility or premises. ESCOs accept some degree of financial risk for doing so. The payment for the services delivered is based (either wholly or in part) on the achievement of these improvements and any other agreed performance criteria.

- **Energy Performance Contracting (EPC)**[42] – a combination of elements from the above two models. The ESCO is responsible for the implementation of the energy saving measures and the operation and maintenance of the lighting system. The payment to the ESCO is based on the actual energy savings. It has high potential for financing modern and energy efficient street lighting solutions, especially in municipalities with limited budget for investments and staff with limited knowledge of street lighting.

For the lighting customer, in this case the owner of the street lighting system, the energy service project can be funded by three alternative models (or a combination of them):

- Self-financing - the customer provides the financing from their own funds
- Debt financing – the customer takes a loan from a financial institution
- Energy service provider financing (third party financing) - the funding comes from the energy service provider (e.g. an ESCO).

Procuring SSL

Most municipal authorities find the procurement process for SSL quite challenging. SSL is a new technology with characteristics that can be very different from the traditional more familiar lighting systems. From the procurer point of view, it is unclear what specifications should be requested. From the supplier point of view, there is great variability in product quality and in the reliability of information provided. Although the number of high quality products is rising steadily, there are still poorly performing products on the market, and these can result in bad experiences that undermine the reputation of SSL technology.

> The European Commission has recently published a set of environmental criteria for Green Public Procurement of indoor and street lighting.

Procurement specifications should be well thought out so that they are leading to the selectionof high quality lighting solutions. Following experience from extensive studies at several European SSL test sites, minimum performance specifications must be defined and applied, to ensure higher acceptance and improvement of SSL luminaires. The performance requirements of SSL should be expressed in terms of existing standards, and, where possible, should follow existing CEN and CENELEC (or IEC and CIE) lighting standards. Several organisations have developed selection tools and guides to assist new buyers of SSL systems[43].

Government procurement regulation in the European Union allows the inclusion of Selection Criteria, Award Criteria and Exclusion Criteria in a public tender. These can be used to prevent procurement decisions being based on pricing alone, and so open the way for procuring more innovative lighting installations offered by SSL technology. Procurers should be able to award points for those aspects that are most important to their specific requirements. Additionally, Member States and public authorities can implement, on voluntary base, the Green Public Procurement (GPP) scheme[44] for procuring goods, services and works with a reduced environmental impact throughout their life cycle.

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[42] **Energy Performance Contracting (EPC)** is a contractual arrangement between the beneficiary and the provider (normally an ESCO) of an energy efficiency improvement measure, where investments towards achieving that measure are paid for in accordance with a contractually agreed level of energy efficiency improvement.

[43] http://www.esoli.org/images/stories/Download/ESOLi_Best_practice_catalogue_Appendix_EN_120426.pdf and http://www.lotse-strassenbeleuchtung.de(In German)

[44] http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdfand http://ec.europa.eu/environment/gpp/pdf/criteria/indoor_lighting.pdf

Training the procurers and the other municipal staff

Many architects and technical consultants lack specific knowledge and experience of SSL and its advanced lighting concepts and design possibilities. Therefore, they often advise their clients that tenders should be based on simple functionality alone, leaving the contractors or suppliers to do the detailed design and technical specifications for the system. Frequently this results in the contractor selection being based on cost alone, without taking due account of other relevant aspects, such as life cycle costing, quality environmental performance or benefits for society.

Having skilled staff within the lighting sectors of municipalities will be essential for changing the patterns of investment and consumption of SSL. However, there is currently a lack of solid evidence-based knowledge within European municipalities of how the planning of lighting should be implemented, and of well-trained staff specialised in the procurement of SSL lighting systems. ESOLi has prepared an illustrative example of a suitable programme for SSL procurement training[45].

SSL technology deployment

Specialist service providers would normally undertake the technology implementation process, so the primary role of the municipality during the deployment would be monitoring of progress and verification of the quality and completeness of the contracted services provided. Verification would cover quantity and location of luminaires, optical performance, and energy efficiency. Certain performance metrics, such as lifetime and self-adjustment, will only be verifiable after a sustained period of operation, and suitable warranty provisions with the SSL contractor would be needed to cover this aspect.

Successful deployment strategies could consider:

- ***Prioritisation***: make initial installations where they will have most immediate benefit. Do not install new lighting where it is not neededbut implement SSL as an integral part of all new infrastructure projects. Choose some high visibility 'demonstration' projects to showcase the benefits of SSL to the community.
- ***Offsetting benefits***: Choose the lighting design that most effectively solves the specific lighting task, balancing function, aesthetics, energy efficiency and economy. For a relatively small investment, good lighting can have a significant impact on the well-being of citizens and enhance their cultural perceptions.
- ***Well-tailored solutions to user-needs***: Adapt the local lighting pattern to match the needs of local businesses and citizen's leisure activities.
- Use improved lighting to encourage greater citizen use of non-motorised transport through providing attractive, well-lit walkways and cycle paths.
- ***Environmental Impact***: Replace & recycle mercury-based lamps to reduce the environmental impact of hazardous materials and use luminaire designs that minimise upward emissions to reduce light pollution.

Further suggestions for optimising deployment of SSL are presented in the PLUS Mainstream Guide[46].

Operations and maintenance

The very long lifetimes offered by SSL systems – in excess of 50,000 hours – present new challenges for municipalities in terms of maintenance. Overall there are very significant cost savings in maintenance operations as with SSL lighting fixtures there will be no more need for frequent bulb replacement due tothe limited lifetime ofthe conventional ones. This is to be somewhat offset by the more frequent cleaning of lamps which needs to be provided particularly for locations such as busy

[45] http://www.esoli.org/images/stories/Download/Training_Summary_of_required_skills_111019_EN.pdf

[46] http://www.luciassociation.org/images/stories/PDF/plus%20mainstream%20guide.pdf

roads where there is high contamination. The capability of intelligent SSL lighting to self-test and implement in-life self-adjustment will have a significant impact on maintenance requirements, as would networked lighting that allows automatic notification of luminaire faults.

A further maintenance issue to consider is unification of the luminaire stock to minimise the number of variants held as inventory for replacements. If such standardisation can be adopted during the planning stage, considerable savings in operational costs will be possible.

Assessing impact and measuring performance

Monitoring the operation of a new SSL installation is important for generating data on overall lighting performance and user acceptance. This data can be used to assess the overall success against the initial plans, and to monitor on-going operational performance. Monitoring will also provide benchmark data against which subsequent performance improvements can be measured.

A very limited number of private European companies have established larger scale testing and demonstration facilities, enabling the testing of lighting designs in an urban environment and natural scale. The Philips OLAC laboratory[47] in Lyon is one of such facilities. It can be anticipated that independent facilities offering impartial testing of SSL components in real-world configurations will be established over the coming years in response to wider deployment of this technology. Ideally, these would offer virtual testing facilities, allowing municipalities to demonstrate technology to decision makers, politicians and citizens groups.

5. LEVERAGING EXPERIENCE

Communicating results achieved and lessons learnt

The sharing of good practice and applicable knowledge amongst decision makers and practitioners is an important way of influencing decisions concerning lighting. Clearly it will only be possible to improve European and national decision making underlying SSL deployment strategies, if well-proven successful examples of lighting solutions can be demonstrated, based on solid documentation and analysis of all relevant aspects (investment, maintenance, energy costs, life-cycle calculations, etc.). This will help overcome the fact that municipalities in many countries are under pressure to choose short-term, economically viable solutions over longer-term, more sustainable and environmentally friendly lighting solutions. It also further serves to emphasise the potential benefits of EU mandated actions, supporting joint, cross-border activities, in parallel with efficient measures for the dissemination of results and best practices.

Varying levels of reporting can be considered, depending on local practice, but could range from annual reports provided to politicians, monthly reports for lighting departments, real-time monitoring reports for maintenance engineers, to readily accessible on-line newsletters for citizens.

Dissemination of knowledge and good practice activities should be targeted towards:

- Lighting planners & staff in municipal technical and environmental departments
- Local citizens
- National and regional level decision makers
- Lighting professionals, advisory engineers, lighting designers and architects
- Other organisations, NGO's and the lighting industry

A wide range of dissemination routes should be employed at the European and national level, including:

[47] http://www.newscenter.philips.com/main/standard/about/news/press/article-15312.wpd

- Registration and collection of good practice lighting projects
- Publishing on the Internet
- Published year books of recent case studies
- Presentation at relevant trade fairs (Light & Building[48], LumiVille)[49] and conferences (EU coordinated, European NGO's)
- European prizes for 'Lighting Project of the Year'[50] or 'Lighting City 2015'[51]

The dissemination task should be organised as a collaborative action between a European coordinating organisation and regional/national based networks or cluster organisations.

Sharing knowledge through associations and communities of practice

More broadly, there are opportunities for mutual support between municipalities through the formation of communities of practice and shared resources. Several of these have already been established, for example, LUCI (Lighting Urban Community International)[52] and ESOLi (Energy Saving Outdoor Lighting)[53]. LUCI has assembled a useful urban lighting database of best practice, accessed via their PLUS website[54]. Similar networks have also been established in the US, for example the DOE Municipal Solid-State Street Lighting Consortium[55], from which a wide range of resources for the evaluation of LED street lighting products are available[56].

To promote such dissemination actions, the EU offers funding for collaborative projects within its multi-annual framework programme for research and innovation[57].

6. MOVING FURTHER AHEAD: VISION OF FUTURE SSL SYSTEMS

Adoption of SSL will result in 'greener' buildings and public areas that use substantially less electricity, providing the means for achieving compliance with the 2010directive for 'near energy-zero buildings'[58]. However, energy savings are only the first step, and intelligent lighting through SSL combined with sensors and digital processors as well as with solar photovoltaicswill provide an essential enabling technology for Smart Cities.

A number of key developments will influence the future deployment of SSL in cities:

Intelligent Lighting Systems: Digital control already allows individual lighting devices to be controlled and offers direct communication between lighting devices and their local environment. This provides possibilities for improved control methods and granularity of lighting controls, such as user interfaces for manual and automatic adjustments in response to daylight availability, occupancy, or time of the day.

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48 http://light-building.messefrankfurt.com/frankfurt/en/besucher/messeprofil.html

49 http://www.capurba.com/lumiville/en

50 http://www.luxawards.co.uk/

51 Reference needed for Lighting City 2015'

52 www.luciassociation.org

53 www.esoli.org

54 PLUS website - www.luciassociation.org/plus

55 http://www1.eere.energy.gov/buildings/ssl/consortium.html

56 http://www1.eere.energy.gov/buildings/ssl/resources.html

57 E.g., the Intelligent Energy Europe programme, aimed at supporting EU energy efficiency policies, http://ec.europa.eu/energy/intelligent/

58 Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings

Adaptive Lighting: SSL can deliver instantly addressable, customised and adaptable light based on the needs or desired mood of the occupants. Dynamic lighting could be used to achieve better educational outcomes, more productive workers and improved health, safety and quality of life.

Health & Well-Being: The quality and type of lighting can impact human health and comfort. Good ambient lighting can relax, soothe or excite. Lighting that could adapt automatically to meet the individual needs will offer great benefit, particularly the elderly and the infirm, but also to students and workers.

Integrated Lighting and Solar Systems & Networked Lighting: The increased intelligence in lighting systems will allow integration with other city systems, such as energy, facility or mobility systems to optimise power smoothing, generation, delivery and monitoring. Smart lighting also provides a data network, allowing for the flow of information between the different city networks, for example to communicate maintenance needs. The lighting network could readily be used to supplement local citizen data networks providing the infrastructure for city-wide wireless communications.

Integrated Lighting and Solar Photovoltaic systems:Increasingly, lighting systems and solar photovoltaic systems will be integrated into smart building envelopes (e.g. as "Smart Windows") to provide dynamically adapted optimal lighting conditions at minimum energy consumption and ultimately to contribute to zero-energy buildings and neighbourhoods.

Wireless Sensor Fusion: Sensor fusion, combining many different sensor types and distributed intelligence within the lighting system, will open many new applications. Sensors could determine the optimum lighting by monitoring occupancy, temperature, energy management, daylight availability, or the presence of RFID tags.

Though some of these developments will take several years to be ready for deployment, others are much nearer term with key features already being investigated through pilot schemes now being deployed[59].

7. RECOMMENDATIONS FOR MOVING AHEAD

Several issues remain to be resolved to further assist municipalities in undertaking widespread deployment of SSL. To address these, a number of recommendations are made:

i. **Create European Buyers Consortia or User Federations:** Establish European Buyers Consortia should to share technical information and experiences related to specific SSL products, building a repository of valuable field experience and product data, thereby accelerating the uptake of SSL. Such consortia could coordinate component testing through the establishment of a chain of European testing facilities, and facilitate collective buying, thereby ensuring unified specifications with consequent volume discounts.

ii. **European Level Finance Initiatives:** Innovative finance strategies for large-scale SSL deployments should be developed to overcome installation cost barriers. Schemes should involve the European Commission, national governments, financial investment organisations (national and European banks), and lighting suppliers, providing financial models suitable for different deployment projects, such as the Public Procurement of Innovative Solutions[60] initiative, aimed at increasing the market uptake of innovative products and services.

[59] http://www.eumayors.eu/IMG/pdf/Covenant_of_Mayors_Case_Study_Albertslund-2.pdf

[60] http://ec.europa.eu/enterprise/policies/innovation/policy/public-procurement/index_en.htm

iii. **European Level Procurement Mandates:** Leveraging community and national procurement powers through mandating changes to public procurement processes will help ensure that SSL technology is actively encouraged for indoor building and street lighting projects.

iv. **Training the procurers:** Providing specific training to public procurers on how to implement SSL-favourable procurement lighting processes will help accelerating the transition to SSL lighting.

v. **Educating citizens:** Significant attention should be paid to citizen education, as this will be critical for SSL acceptance. This is best performed in partnership with industrial stakeholders, energy efficiency sponsors, and state and local governments. SSL awareness demonstrations linked with local R&D and suppliers would provide an effective means of achieving this. There is also a strong need to educate the potential buyers on SSL technology, addressing procurement, specifications, verification, and likely energy efficiency and maintenance cost savings.

vi. **Gateway Demonstrations for moving to Smart Cities:** Major technology demonstration actions are needed to showcase intelligent, interconnectedSSL lighting solutions implemented in cooperation with municipalities. Such 'Lighthouse' projects should explicitly demonstrate the potential commercial benefits that an EU city will have in moving towards *a smart city approach*.

vii. **Smart Specialisation and promotion of innovative SSL lighting solutions:** Include large demonstration and procurement actions of innovative SSL lighting solutions as part of the regional specialisation strategies (new cohesion policy), thereby ensuring that the great potential for innovating future SSL can be realised while promoting the local & regional business innovation potential.

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Glossary:

EPC	Energy Performance Contracting
ESCO	Energy Service Company
LCC	Life Cycle Costs
LED	Light Emitting Diode
OLEDs	Organic LEDs
SSL	Solid State Lighting
TCO	Total Cost of Ownership