A Cities' Guide to Smart Lighting

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A white paper from cities for cities — about the why and how behind Smart Lighting

LUCI ASSOCIATION

Foreword

Nothing is magic about smart. It always comes down to **who** is actually behind the machines and the systems, and how we can harness innovation in a meaningful way for our societies. Smart lighting, as one of the components of the modern city forces us:

- to think about **the inextricable link between the material and the digital** in the city: how the intangible space of data and algorithms have consequences for the tangible use of public space (and vice versa);
- **to reposition the individual vis-a-vis the collective**: from an overall, comprehensive vision of public lighting to a more granular approach, from a collective public policy to a more personal feature of the city, from "our" lights to "my" light;
- **to re-examine the objective vs the subjective** experience of the city after dark.

As cities, **let's take a bit of time to reintroduce some social depth and political perspective** into a set of decisions that are never neutral. Let's introduce other expertise such as psychology and philosophy to tackle the challenges of these new technologies. Let's create more exchange and cooperation opportunities between engineers and designers, between layers of government and citizens, between centre and periphery, to make the best of our scarce global resources and add value and mutual trust to our local communities.

This concise publication tries to answer this challenge and has one specific, truly genuine, goal: **to enable decision makers to develop a richer vision of these issues linked to smart lighting** and take steps considering a wider approach to urban lighting itself: how the public space is used after dark and how light can be useful to our societies in a sustainable way.

Smart lighting plays a key role in the future of urban lighting. Find out why and how in this brilliant co-created guide – by cities for cities.

Meri Lumela
President of LUCI
Deputy Chair of the City council of Jyväskylä

Summary

THE CONCEPT OF PUBLIC LIGHTING is changing due to the emergence and adoption of 'smart' technologies such as advanced sensing, control and communication possibilities. Cities are confronted with the question of how to deal with developments towards Smart Lighting. How can we ensure that these developments benefit the city, its citizens and the common good? LUCI Association picked up on such questions within its network and created this White Paper to help cities form their vision on Smart Lighting and support possible actions towards realisation.

This paper brings together two different frameworks for Smart Lighting that tend to be treated separately, namely a technical/operational framework (e.g. aiming for efficient operation and energy savings), and a social/societal framework (e.g. light for wellbeing, social implications of lighting and citizen rights considerations).

Based on both frameworks, we treat the question 'Why Smart Lighting?', and discuss how Smart Lighting can contribute to a broad range of topics: environmental sustainability, social sustainability, citizen value, the city's internal organisation and more.

Next to that we describe external factors that push towards Smart Lighting, such as the general trend of electronic hardware becoming part of an IT network, the so-called Internet of Things. Although Smart Lighting could be beneficial for multiple reasons, it should never be seen as an end in itself. We therefore also treat reasons why or when not to venture into Smart Lighting, based on possible downsides. Questions of 'Why?' are inevitably followed-up by questions of 'How to?', when a city wants to take steps. We identified a number of 'How to'-questions that live among LUCI members, and gathered insights from experts, literature and practical examples to help cities make progress.

We list possible ingredients for making an internal case for Smart Lighting, also looking beyond lighting; we treat ways to organise the necessary expertise; we highlight techniques for engaging citizens; and we touch upon data management.

Interoperability, the ability of different devices to work fluently together, is a key issue and we describe possible ways to understand and deal with it. Tendering for interoperability is addressed, indicating how cities could jointly make a difference in the market for interoperable products and systems.

This white paper cannot incorporate all relevant topics and it can only briefly touch upon the selected ones. For those who would like go more in depth or learn more about adjacent topics, this paper concludes with a list of helpful resources.

Introduction

WHY THIS WHITE PAPER?

Cities worldwide are facing the question of how digital and connected technologies could, or should, impact their public services. Public lighting is a potent driver for transformation of public space, due to the simple fact that lighting infrastructure in the city is present wherever people are. Lighting brings together technological infrastructure, citizen needs and governance of public space in a direct way, making it a fruitful area for envisioning and building future public space.

The field of "Smart Lighting" is emerging, enabled by advanced sensing, communication and control technologies, causing the concept of public lighting to change. But how to deal with this rapidly developing, multi-faceted field? What could be the motivations to take steps in this direction? And how could it be applied to the benefit of the city, its citizens and the common good? This paper aims to help cities with the questions "Why?" and "How to?" behind Smart Lighting to help decision-making and possible action in this field.

FROM CITIES FOR CITIES

This white paper is an initiative of the LUCI Association, a non-profit international network of cities on urban lighting, with over 70 member cities and 50 associated members from the lighting industry, design agencies and research institutes. This paper is a joint effort of LUCI members in collaboration with external experts. It is part of the EU Interreg NWE funded SMART-SPACE project and is written with the EU as frame of reference. LUCI has no commercial interests. This paper is from cities, for cities, with the interest of cities and their citizens as the main driver.

We strongly believe in the values and goals laid out in the following documents: The LUCI Charter[1], the New Leipzig 2020 Charter on Sustainable Cities[2], the UN Sustainable Development Goals[3], and Join Boost Sustain EU[4]. The values and visions set out in these documents should be seen as backdrop for this White Paper.

SCOPING SMART LIGHTING

We write Smart Lighting with capitals to indicate it is a container term that should not be taken literally. The term encapsulates many interpretations. And even within a given interpretation, the technological and social implications are still intricate and manifold. We have no ambition to provide a fixed definition of the rapidly developing field of Smart Lighting.

For this paper we use the following minimum technical criteria for a lighting system to be called Smart Lighting: The system includes elements generating data (e.g. lights, sensors, controllers), elements responding to data (e.g. controls, lights) and one or multiple elements making control decisions (e.g. a lighting management system), all of which are united in a communication infrastructure. But in treating Smart Lighting, we cannot limit ourselves to these technical criteria. We highlight **two different but common frameworks for discussion of Smart Lighting** to create a scope that does justice to the topic:

1. **Technical/operational framework:** A set of technologies and practices that enable greater operational efficiency. This discourse focuses on technologies and processes 'under the hood' that support quantifiable goals, such as energy savings and reduced operational costs. For example, application of technologies such as wireless modules that report a luminaire's energy use and maintenance needs in real time to a central management system, or smart traffic sensors that provide input for adaptive luminaire dimming.

2. **Social/societal framework:** A set of technologies and practices that enable lighting systems to influence life in public space in new ways. This interpretation looks more into the possible effects, advantageous or disadvantageous, on people in the city in relation to their needs. This discourse is qualitative, since it is about subjective concepts like atmosphere, perception, meaning, human behaviour, etc. Goals are described in qualitative terms as well: light for wellbeing, light for identity, etc.

We highlight these two frameworks for viewing Smart Lighting here because they tend to be treated separately, rather than in parallel, or one is under- or over-emphasized compared to the other.

In this paper, we stress that both viewpoints are important, intertwined, and should be integrated for optimal practice. Offering lighting that can adapt to different cultural activities in an area (social/societal framework) will need a viable, technical infrastructure with sufficient communication possibilities that at one point passed budget approval (technical/operational framework). Installing smart cameras for efficiency purposes such as traffic based dimming (technical/operational) without considering citizens' worries about privacy and surveillance (social/societal) can end up in failure or severe delay[5]. In this paper, Smart Lighting is treated from both viewpoints.

SCOPE OF THE WHITE PAPER

This paper is not about LEDification (the replacement of 'traditional' light sources by LED sources). Although LEDification is often a trigger for moving into Smart Lighting, there are ample other sources about this topic. Lighting is at the heart of this document, but it is a small step from Smart Lighting to adjacent 'Smart City' functionalities. We touch upon such functionalities, such as traffic management, where these functionalities are strongly related to Smart Lighting or where combining them with Smart Lighting could be beneficial. We treat a number of enabling technologies, such as open communication protocols, but we will generally not elaborate on technical aspects. We will address their potential, their possible implications for the city and its citizens and ways to deal with them. We build on examples from practice and academic sources where available. We also occasionally treat near-future developments and envision their implications.

Not all cities are the same so not everything in this paper is equally relevant to each city. There are large differences in terms of lighting infrastructure, applicable legislation, local needs and cultural values. It is even too simple to speak of *the* lighting infrastructure of a city: a city could have a mixture of Mercury, HPS, Fluorescent, LED and other luminaires in different ratios, a mixture of brand-new plastic insulated low-voltage cables and 90-year old lead paper cables, even with intermittent power supply in some regions. Given the substantial differences between and within cities, we invite the reader to use from this paper what is relevant to his or her specific context, and to leave what is not.

1. Why Smart Lighting?

At the deepest level, Smart Lighting should contribute to realising the values of a city: it should help achieve the goals a city strives for, for itself, its citizens and society.

BEFORE VENTURING INTO Smart Lighting, it is essential to ask the question: Why should we? To what end? At the deepest level, Smart Lighting should contribute to realising the values of a city: It should help achieve the goals a city strives for, for itself, its citizens and society.

How should public space support the citizens after dark? Is it to get from A to B as efficiently as possible or is there more? Incorporating such questions in the decision-making helps set the stage for meaningful applications of technology. These questions also may prevent a 'technology-for-technology's sake' approach to Smart Lighting, which could even lead to negative consequences in public space. Next to these vision-based questions there are practical yet important considerations, like available resources, existing policies and contracts, infrastructure, etc.

In this section, we address a number of reasons why Smart Lighting could be relevant to your city. These motives stem from both the technical/operational and the social/societal framework. Each city is different in terms of their value priorities and practical considerations, so not every reason we mention is as relevant to one city as to another. Based on the LUCI Charter,[6] the Leipzig 2020 Charter on Sustainable Cities[7] and the UN Sustainable Development Goals,[8] we believe however that many of the following reasons why should be seriously considered. We end this section with reasons why *not* to venture into Smart Lighting, because it is not automatically the answer to all questions.

1.1

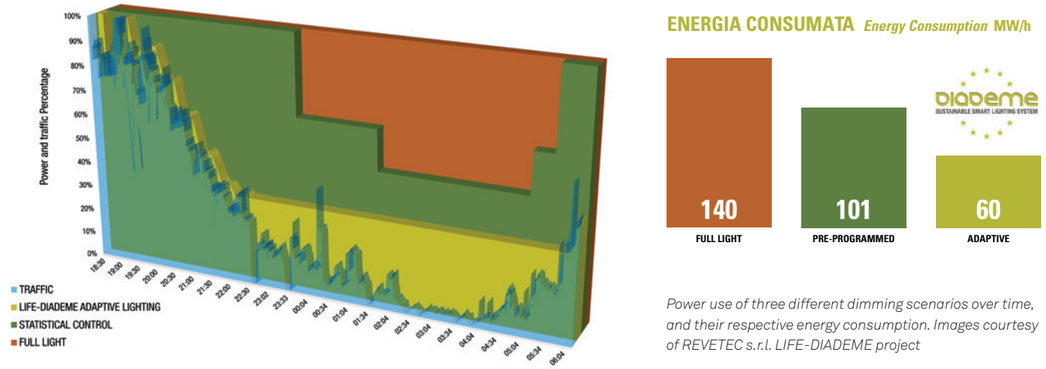
Environmental Sustainability

THE UN SUSTAINABLE DEVELOPMENT GOALS[9] leave no doubt how important it is to reduce negative impact of human action on our world. Governments around the world pledge to achieve carbon neutrality before 2050. Lighting is an opportunity to contribute to these goals. We see three ways in which this is possible: energy saving, protection of biodiversity and minimizing light pollution.

ENERGY SAVING AND CO_2 REDUCTION

"If a tree falls in a forest and no one is around to hear it, does it make a sound?" If this conundrum was about public lighting with no one around to see it, we could confidently say that energy would be wasted. Smart Lighting can contribute to a solution. Adaptive dimming behaviours responding to traffic and weather conditions can make a significant difference. The LIFE-DIADEME project[10] reported that street lighting adapting to traffic and weather used 41% less energy compared to fixed pre-programmed dimming schemes, in one year of testing. The project states that "Assuming that LIFE-DIADEME is installed in a big city with more than 200,000 lighting points as, for example, Rome, if we consider the average life of lighting fixtures, savings in environmental terms would result in 40,000 tons of CO_2eq, 8 tons of PM2.5, 48,000 kg equivalent of Ozone and lower acidification that we estimate near at 95,000 MLC H+ equivalent."[11] Sedziwy et al.[12] reported 34% energy saving in a 1-year trial with 100 luminaires comparing a static calendar approach to an adaptive approach responding to traffic density. The actual savings potential in a city will of course depend on the specific setting and traffic behaviour.

Even further energy saving could be achieved by making more use of the characteristics of human perception, like the relative nature of brightness perception, adaptation to dark, etc. Lighting schemes can be created that use less energy while achieving satisfactory or improved perception of the environment.[13] Smart Lighting could also contribute indirectly to CO_2 reduction by creating environments that are more attractive, comfortable and safe for pedestrians and cyclists at night, for example with adaptive lighting at pedestrian crossings, enhancing their visibility when crossing a street.[14]



Power use of three different dimming scenarios over time, and their respective energy consumption. Images courtesy of REVETEC s.r.l. LIFE-DIADEME project

Minimising light pollution of all kinds should be a key consideration.

MINIMISING LIGHT POLLUTION

The International Dark-Sky Association defines light pollution as any adverse effect of artificial light. They identify glare, skyglow, trespass and clutter as components of light pollution[15]. These 'side-effects' of artificial light disturb ecosystems, harm human health and well-being by disturbing sleep-wake cycles, cause discomfort, and deprive people from the sight of the stars. Minimising light pollution of all kinds should be a key consideration.

More than 80% of the world and more than 99% of US and European cities have light-polluted skies due to skyglow[16]. Kyba et al[17] used Tucson's Smart Lighting system to investigate the contribution of public lighting to the total amount of city light radiated into space, by dimming 14,000 of its 19,500 streetlights to 30% on some nights where they are normally dimmed to 60% at night. Satellite measurements show that streetlights contributed to 14% of total artificial light in the sky. Tucson is an astronomer's town with street lights optimized for reducing skyglow, so in other towns this component could be larger. Interestingly, the 30% dimming scheme raised no complaints: eyes adapted.

Smart Lighting increases the city's ability to realise bolder dimming behaviours where possible, contributing to reducing light pollution.

Smart Lighting increases the city's ability to realise bolder dimming behaviours where possible, contributing to reducing light pollution. Another important lesson is that most skyglow comes from other sources than public lighting. Smart Lighting, in combination with new governance models, could offer new ways to align public lighting and private lighting in public space, like advertising and facade lighting, to decrease light pollution. See for example the pilot in Sint-Niklaas exploring just that[18].

PROTECTION OF BIODIVERSITY

Artificial light at night can impact biodiversity negatively. It can disturb sleep-wake cycles of fauna, negatively impact reproduction and population sizes, disturb migration and much more[19]. The scale of this impact depends on factors like location, duration, timing, direction and spectrum. Research about which wavelengths in which periods are more or less straining on which species is ongoing. Longer wavelengths (reddish light) seem to generally be less straining than shorter wavelengths (blueish light), although this is not true in all contexts[20]. Narrow spectrum sources are picked up by fewer species because of differences in wavelength sensitivities between animals, and less light is generally less straining[21].

It should be clear that dimming schemes that reduce the total amount of light can be beneficial for biodiversity as well. Looking into the future, dimming schemes could also respond to animal presence or migrating routes and periods. It is also not unfeasible to tailor spectral composition of light to specific animals' visual sensitivities, to disturb them as little as possible[22]. Tools to assess impact of light spectra on specific animals are available[23]. Note that humans are animals with sleep-wake rhythms that could benefit from these endeavours as well. Research into these issues is ongoing, e.g. in the ENLIGHTENme project[24].

NEGATIVE ENVIRONMENTAL IMPACT

Smart Lighting also presents downsides in terms of sustainability. Any added electronic device, cable or signal in the end puts strain on nature, be it in terms of future waste, electromagnetic radiation or energy to manufacture and transport. Incorporating demands on circularity of devices in tenders will contribute to reducing negative impact.

1.2 Maintenance and Asset Management

SPECIFIC SMART LIGHTING TECHNOLOGY helps the city keep track of the state and performance of all connected streetlights. Different types of failures and electrical issues are detected by the system and reported to the maintenance department. This helps reduce maintenance costs while increasing maintenance efficiency. Defects are detected earlier, the need for citizens to report failures is reduced, and the mechanic can better prepare the repair knowing more about the problem in advance. This can also reduce the time to fix the problem.

Adaptive dimming, which is simply dimming the lights when there is no traffic, extends lifetime of the LEDs and drivers through lower overall power consumption. This in turn reduces maintenance costs. The streetlight inventory of many cities is only 80% accurate. Smart Lighting technology helps create overview in several ways. Smart lighting controllers installed at each light point, can report their geographical position by means of Global Positioning System (GPS) or location information that is entered at installation. Next to this, relevant information about each luminaire, such as manufacturer, model, type of LED driver, power consumption and more is available for consultation via a central software interface. All these functionalities contribute to smoother maintenance and asset management.

1.3 Social Sustainability

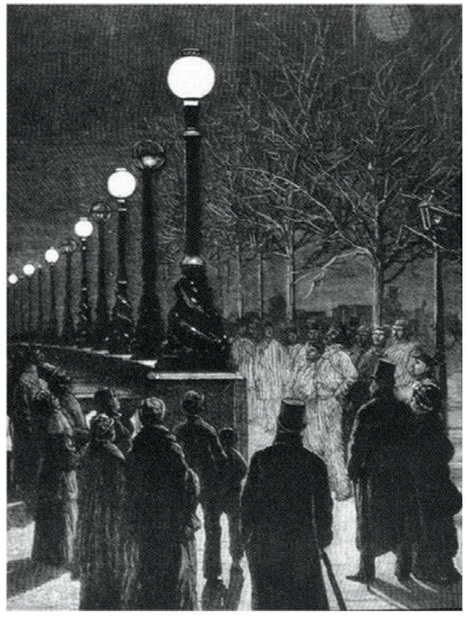
IN OUR VIEW, Social Sustainability should be anchored in a city's ambitions with Smart Lighting. Social Sustainability pertains to UN Sustainable Development Goal 11[25] and includes aspects like liveability, community development, human rights, placemaking, social responsibility, cultural competence and community resilience. The UN projects that the percentage of the world population living in cities will increase rapidly, up to 68% in 2050[26], underlining the growing need for socially sustainable public space, also at night. Smart Lighting could contribute to such goals, but achieving this is not trivial. What could be the relation between Smart Lighting and Social Sustainability?

This question requires us to take a social/societal viewpoint to lighting. People tend to take public lighting for granted and may not be aware of the enormous societal impact it had when it became widespread. Before gas/electric street lighting, the sparsely lit nocturnal public space was the realm of thieves and hustlers.

Public lighting has a social impact... and different lighting schemes have different social implications

Better public lighting made public space social at night, offering an environment that felt safer, more readable and more comfortable[27] [28]. Public lighting still has this social impact, although we do not always place it at the foreground, and different lighting schemes still have different social implications[29].

When lighting becomes Smart, even more layers of social impact emerge: How do people feel about sensors monitoring public space? Does it increase their feeling of safety? Does it diminish their feeling of privacy? Can adaptive dimming schemes influence pedestrians' feeling of safety? Since Smart Lighting impacts public space (a space that citizens cannot and should not want to avoid) by means of lighting changes and possible data gathering, extra care about social implications is required.



Public demonstration of bright Jablochkoff Candles at Victoria Embankment in 1878. Source: Wikimedia Commons

To ensure lighting can contribute to Social Sustainability, municipal decision makers are advised to adopt the social/societal framework of viewing Smart Lighting simultaneously with the technical/operational framework in their decision-making process. Social consequences can never be fully determined, but they can be taken into account in different phases of a project to increase chances of positive results[30]. Neglecting the social/societal dimension of Smart Lighting does not make social implications disappear. Social damage could occur unintendedly and potential social benefits may remain unattained.

Examples of social 'collateral damage' in Smart City are readily available. See for example the case in San Diego[31] where use of streetlight cameras for surveillance sparked controversy that eventually led to shutting down all streetlight sensors pending better surveillance policies. As more advanced sensors, such as smart traffic cameras, enter Smart Lighting applications, these kinds of issues become ever more prominent in the Smart Lighting domain.

Public bodies bear a responsibility for Social Sustainability, so they should take the lead in deciding how Smart Lighting is applied in public space... Smart Lighting is politics in technological form

Note that the social/societal view on Smart Lighting brings in ethical questions. What kind of impact is desirable in this specific community? This is not a matter of simply finding something acceptable or not, and it stretches far beyond privacy matters that are normally a focus of ethical debates around Smart Lighting.

Social Sustainability does not always need to be about grand changes. Goals for Smart Lighting like enhancing the cultural identity through light, enabling the visually impaired to better navigate the city, responding to cultural events with light and involving citizens in programming lighting schemes, are useful pursuits next to more fundamental steps like opening up all data gathered in public space for citizens so they can use it to better participate in governance of public space.

Public bodies intrinsically bear a responsibility for Social Sustainability, so they should take the lead in deciding how Smart Lighting is applied in public space. This cannot be left to industry or chance. Smart Lighting is politics in technological form that enters the street level. Let's not only avoid negative outcomes, but also see Smart Lighting as a chance to enhance the societal values of public space.

1.4

New lighting possibilities for cities and citizens

SMART LIGHTING HAS THE POTENTIAL to create new benefits for citizens in countless ways. We name just a few to give an impression:

- It could enhance identity and culture: a city could support cultural events by activating related temporary lighting scenes;
- It could enable more citizen input into their local public space: single luminaires that give unwanted glare into a home can be adjusted. Experiments with temporary citizen control of light scenes in their local square or park have been conducted;
- It could help create a safer environment: for example, in emergency situations light could help citizens evacuate an area and assist emergency services with full brightness;
- Light can be catered to citizens with special needs in specific areas;

- It could also help make biking or walking more attractive, see for example, the dynamic cyclist tunnel lighting in the Greater Copenhagen region that adapts to outdoor light levels while creating an atmospheric effect[32].

Pilot projects in Lund and Albertslund[33] show how some of these possible benefits could be achieved. The document *The Value of Smart Urban Lighting*[34] lists a large number of application examples that are relevant for citizens.

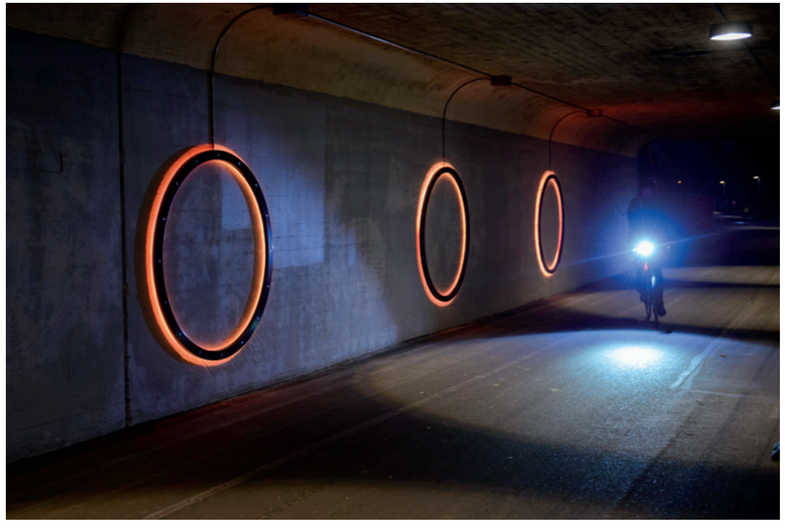
1.5 Enable functionalities beyond lighting

ONCE A FUTURE-PROOF power and connectivity infrastructure for Smart Lighting applications is realised (see section 2 for more details), a myriad of new applications becomes possible with less investment. Such applications are often referred to as 'Smart City'. The infrastructure becomes a platform for flexible further development in the future. Compare, for example, how a general technology like WiFi opened up many new functionalities in the home and office and continues today to enable new applications that were not even imagined yesterday.

Smart Lighting infrastructure, and the investments it requires, can be seen in that sense: creating a platform for the city that enables the applications that are needed now, plus applications that will be beneficial in the future. Without being exhaustive, we treat a number of interesting examples in the following:

- Sensors like Passive InfraRed (PIR) or radar detectors installed on the streetlighting poles can give an indication of density of traffic. Cameras with advanced image recognition can differentiate between different kinds of traffic. This high granularity and steady stream information can be used to identify traffic or safety issues, especially when near-misses are included in the analysis[35]. Parking assistance applications using pole mounted sensors are being piloted.

- Air quality can be monitored by measuring dust particles and gasses (e.g. Carbon Monoxide, Carbon Dioxide, Oxygen, Hydrogen, Nitrogen Dioxide and Sulphur Dioxide)[36]. In combination with traffic information, this could give an impression of how one influences the other.



Adaptive tunnel lighting in Gladsaxe Municipality, Greater Copenhagen region. © Cycle Superhighways

- By using Bluetooth beacons or other technologies such as perhaps LiFi, the Smart Lighting infrastructure can enable localization applications without using satellites[37]. Citizens could also be provided with WiFi or 5G or other connectivity.

- Street lighting poles with charging equipment enable citizens to charge their electric vehicles, like bikes and cars. Examples exist of pole mounted information or advertisement displays.

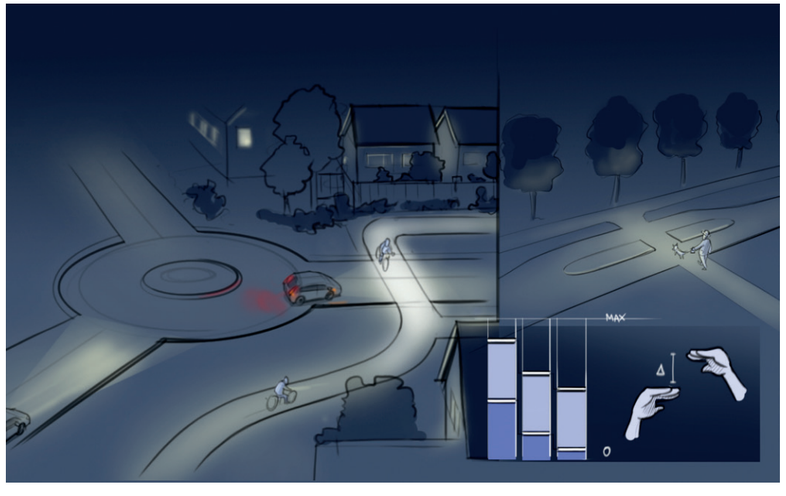
'Smart Pole', is an often-used term to describe the combination of 'Smart' hardware such as mentioned earlier with the street lighting pole. The Smart Pole is starting to emerge in cities. The shared connection advantages are clear. It could also decrease hardware clutter in public space, although the clutter problem could re-emerge on the poles.

There are different interpretations of the Smart Pole concept: on one end of the spectrum the pole is viewed merely as a physical facility to mount and connect sensors and other devices. Sometimes this

even happens without installing dimmable lighting, missing out on potential interplay of light and the generated data. The term 'Multi-Pole' is also used for this concept.

On the other end of the spectrum, there are more integrated concepts like CENT-R from Rotterdam. This initiative turns the lamppost into a modular system that allows flexibility in functionalities and hardware depending on changing needs[38]. Smart Poles need to be viewed as parts of a larger system. For example, an ambition for large scale e-charging on the poles needs to consider possible limitations of the city grid.

In general, it is worthwhile to consider and discover how the Smart Lighting infrastructure can offer value beyond lighting. At the same time, gathering and combining data from Smart Pole devices brings up ethical, privacy and data management issues that we also touch upon in this paper. And it remains important to uphold lighting quality amongst all other considerations.



'Providing good visibility of cyclists and pedestrians crossing the road to increase their (perception of) safety: with multiple lighting scenes that dim further over the course of the evening and night, with constant contrast for a brightly illuminated crossing, a bicycle/footpath levelling up and down towards this intersection and a maximum dimmed or no lighting on the main road.' [Valkenburg & den Ouden, 2021]

1.6 Organisational growth

Smart Lighting offers an opportunity for more 'horizontal' collaboration, across departmental borders within the city organization

TECHNOLOGICAL INNOVATION REQUIRES organizational innovation. Because of its multidisciplinary nature, Smart Lighting offers an opportunity for more 'horizontal' collaboration, across departmental borders, within the city organization. Smart Lighting initiatives often stimulate lighting professionals to connect to other verticals, like traffic, waste and data management. Learnings from pilot projects can inform future decisions about how to organise multi-disciplinary activities within the municipality.

Given the trend of the connected society in which data flows from one domain to the other and the cross-disciplinary nature of society's biggest challenges, the ability to deal with such challenges will be beneficial, if not essential. Next to this, the kind of challenges and vision behind Smart Lighting initiatives can help attract talented new employees who are interested in value driven initiatives and innovative technologies.

1.7 Cross-sectoral technological trends

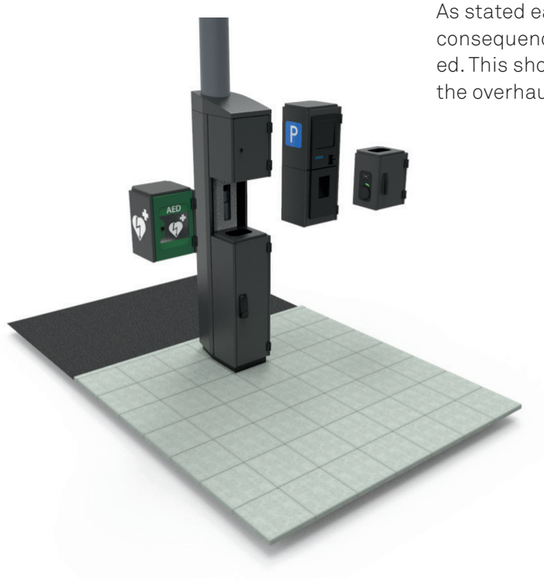
"Digitalisation is a major transformative, cross-sectoral trend affecting all dimensions of sustainable urban development."
[Leipzig 2020 New Charter on Sustainable European Cities]

NOT ALL MOTIVATIONS to venture into Smart Lighting are internal. There are also external factors to consider. In some countries, there is increasing demand for incorporating communication technologies like 5G, the successor of 4G wireless network technology. Street light poles are eyed as a physical carrier of the 5G antennae, even though in many cases 24/7 power and glass fibre for connection to the lighting poles is yet to be realised. Electrified mobility is another external factor that brings in considerations to enhance the street lighting infrastructure. Smart City ambitions often rely on street lighting infrastructure as carrier for sensors and connectivity devices. So at one point lighting departments can expect questions from other parties.

In general, there is a cross-sectoral trend towards connected devices. Compare how Closed-Circuit Television (CCTV) has made

the transition from analogue to digital networks with IP cameras. Similarly, indoor professional office lighting infrastructures increasingly turn from electrically switched schemes into IT networks with IP addressable light points. At one point, compatibility with other systems and availability of components will require lagging systems to move towards the IT model.

This external pressure does not mean technologies should be adopted without considering how to do this in the best way and when. As stated earlier, applying technologies has social and political consequences as well, be they large or small, intended or unintended. This should be considered, even when the initial motivation of the overhaul is technical.



CENT-R modular system integrating 'Smart City' hardware into one physical unit. © Concept CENT-R created/ developed by the Municipality of Rotterdam & Lightwell

1.8

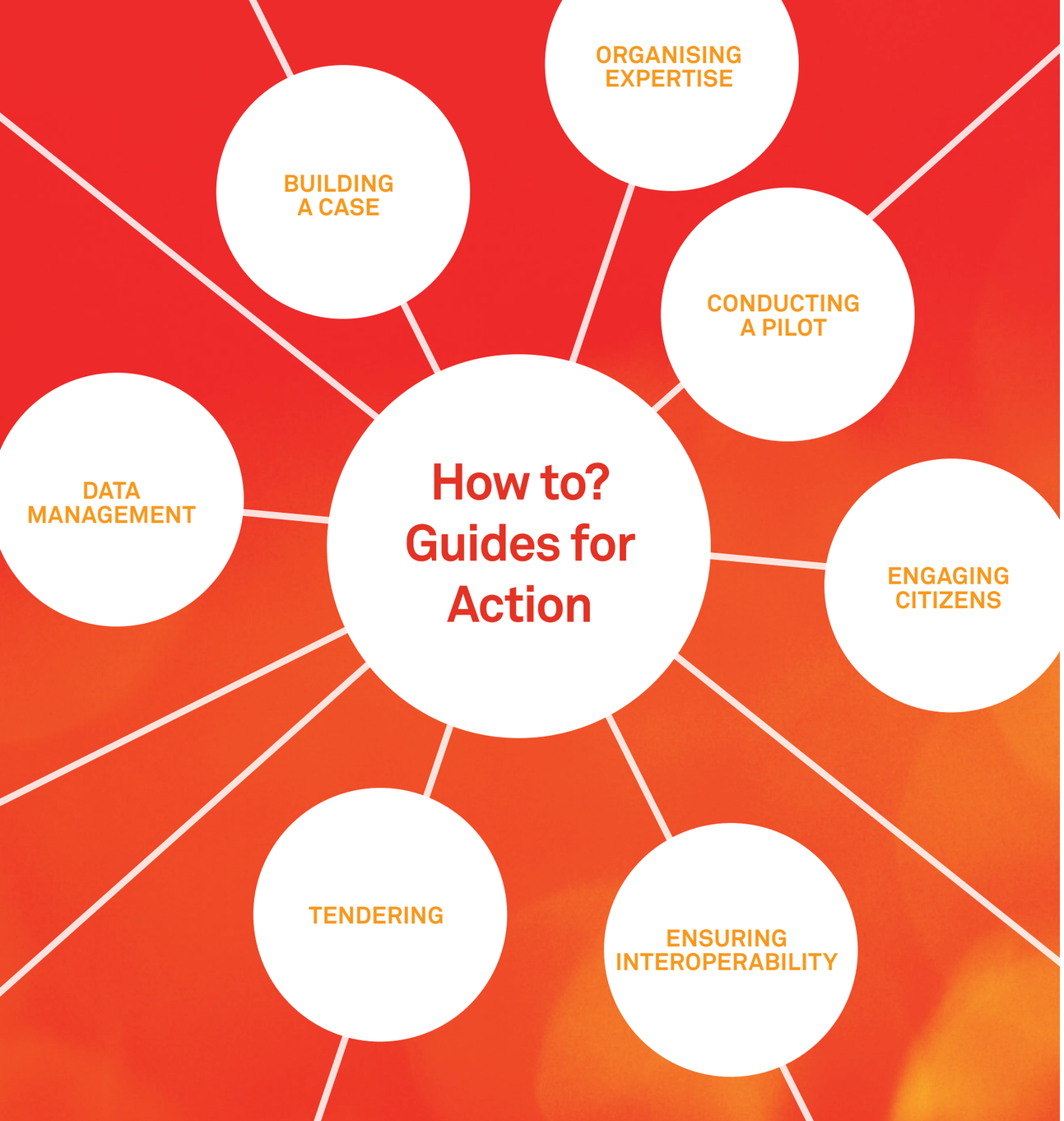
Why not Smart Lighting?

EACH CITY AND COMMUNITY has its own needs, wishes and points of departure in terms of lighting infrastructure. We should not see Smart Lighting as a goal in itself, but rather as a means to achieve goals like environmental sustainability, social sustainability, better lighting, better operational processes and more. Like any technology, Smart Lighting has downsides as well as upsides. The balance between the two is in our view strongly dependent on how Smart Lighting is applied and governed.

Applying technologies has social and political consequences as well, be they large or small

We identified some circumstances that bear the risk of tipping the balance to an undesired outcome:

- There is no citizen involvement or assessment of impact on citizens incorporated in the project: Neglecting citizens in the process increases the risk of negative impact on citizens and decreases the chance of a positive impact. Negative responses can be as varied as complaints about dimming behaviours to citizen protests against data gathering. In case Smart Lighting upgrades happen simultaneously with LEDification, citizens might also worry about the quality of light and health issues related to light colour temperature.
- Anonymised citizen data, extracted from public space, is kept inaccessible for public use, for example in a private repository: Data generated in public space belongs to the public[39]. Anonymised data from public space should therefore be used for the common good, with socially responsible use, management and sharing.
- A city's freedom to act, or autonomy, is threatened to be compromised due to a too extensive transfer of ownership and control of public street lighting assets to a commercial party.
- Data management and cybersecurity are not well embedded in the project: data from public space is potentially sensitive data. In the absence of good data management and cybersecurity, the risk of sensitive data leaks increases.
- There is insufficient attention to concerns of city staff: Smart Lighting has shown to raise concerns ranging from complexity of maintenance and newness of technologies to losing jobs due to automation. These worries should be taken seriously. Without sufficient support base, projects fail.
- There is not enough expertise available in the city to prepare, develop, realise and maintain a Smart Lighting project.



2. How to? Guides for Action

This white paper is here to support cities in decision-making and taking possible steps in the realm of Smart Lighting. We gathered experiences, advice and approaches that we consider helpful from our members and external experts and bundled them in this section.

2.1 Building a case

AT ONE POINT in the municipal decision-making process, a case needs to be built that allows potential gains and opportunities to be weighed against potential costs and threats. Since each city has its own priorities, legal framework, resources, etc., there is no fixed blueprint for building such a case. There are however several substantial ingredients we would like to bring to the fore, to be judged in the specific context of your city.

PAYBACK PERIOD CASE

The projected Payback Period, the time needed to recover an investment, is an often-used metric in municipal decision-making. It is sometimes called the Return on Investment (ROI) period. Such a calculation for Smart Lighting is not so obvious, since it depends on hardware and software choices, contracts, points of departure that will differ per city or project. A number of examples may help, though, to give an idea of the feasibility of such a calculation.

The recent replacement effort of Sibelga in **Brussels Region** included three layers: luminaires, control hardware such as gateways and luminaire controllers, and a central management system[40]. The expected Payback Period of this effort is 6-8 years, based on reduced energy and maintenance costs. Note that the benefits that are not expressed in Euros, such as a better service to citizens, are not in this calculation.

The LIFE-DIADEME project reports an expected Payback Period of 2-3 years, based on a Life Cycle Cost Analysis and Life Cycle

Assessment[41]. Note that in the LIFE-DIADEME case, functionalities beyond lighting were incorporated as well, such as air quality metering and noise detection.

The actual projected Payback Period is of course dependent on the current situation, energy tariffs, required investments, and whether other 'verticals' in addition to lighting are included (waste management, water level management, parking guides, etc.). It also depends on what kind of costs and benefits are considered. For example, which operational savings are considered (energy, maintenance, monitoring, carbon tax savings, etc.) and what adjacent aspects, like employee training costs, are included.

Brussels region public lighting operator, Sibelga, has been implemtenting a step-by-step deployment of intelligent streetlights across the city. Image © Sibelga

Budapest has used a combination of purchase costs, energy savings and warranties in their tender for 'Smart Lighting-ready' luminaires, which led to an attractive projected Total Cost of Ownership.

In the Spanish town of **Gijón**, the data from the lighting system is integrated with data from other 'verticals' such as water meters, motion sensors, parking sensors and waste container sensors. Their case incorporates savings on operations made possible by insights and applications due to new combinations of data from these different verticals[42].

Financial constructions are relevant but beyond the scope of this white paper. We refer to the 'Helpful Resources' for a reference to more information about this topic.

Payback Period should not be the only consideration. The following sections outline more aspects, both technical/operational and social/societal, that can contribute to an extensive analysis of costs and benefits, either quantitively or qualitatively.

SUSTAINABILITY CASE

We feel that sustainability should be an important driver in a case for Smart Lighting. Smart Lighting can deliver here as we have seen in section 1. For example, energy-savings up to 41% is reported thanks to adaptive dimming compared to regular pre-programmed dimming schemes[43]. This is without counting the substantial savings that come from replacement of 'traditional' sources with LED. In Lyon, this combination of LED replacement and adaptive dimming resulted in 70% energy savings[44].

Adaptive dimming can help reduce light pollution as well. And in case the sustainability strategy includes spectral control to reduce impact light on flora and fauna, a scientific quantitative assessment tool is available that helps compare impact of different spectral settings[45]. Evidence of contribution of streetlighting to light pollution is available[46] for citing in your case.

SOCIAL SUSTAINABILITY CASE

The UN goal 11 'Make cities and humans settlements inclusive, safe, resilient and sustainable' should give a strong incentive to include the potential social benefits of Smart Lighting in a decision-making case. The Social Sustainability case does not lend itself easily to a quantitative Return on Investment calculation, although there are initiatives to systematically assess these factors, such as Social Return on Investment by the World Health Organisation[47]. Section 2.3 describes pilot examples and concepts of how Smart Lighting could support citizens in multiple ways.

EXPLAINING THE POTENTIAL OF INFRASTRUCTURE

The foundation of the house of Smart Lighting, i.e. the groundwork behind the scenes to enable Smart Lighting applications, can be an abstract, invisible and technical topic, which makes it hard to explain (and sell) to the public and political decision makers. A communication infrastructure is costly, while it is incapable of producing even one lumen.

The **City of London** embedded investments in infrastructure in a larger lighting strategy. When they needed to decommission their 30 year old street lighting, they enlarged their scope from safety and crime prevention towards creating a cultural and social city nightscape[48]. They desired more elaborate control of single light points to allow light and darkness to be better balanced[49], which brought them to implement a Smart Lighting infrastructure. In light of London's Smarter City vision, they ensured that their Lighting Management System offers the possibility to be coupled with sensors in the city that monitor pollution, traffic flows, and more.

A future-proof power and communication infrastructure can serve as a spring board for additional applications beyond the original design that take advantage of the investments already made. Early adopters experienced this in the field. For example, the **City of Eindhoven** was able to build a new traffic insights project on top of an existing Smart Lighting infrastructure[50]. These future benefits are however difficult to account for in a first Payback Period/ROI calculation, but they are a significant factor to consider in decision-making.

A future-proof power and communication infrastructure can serve as a spring board for additional applications beyond the original design

The City of London embedded infrastructure investments in a larger Smart City vision. Image © Jason Hawkes, City of London Lighting Strategy

Having a clear view of future goals helps bring down costs for the infrastructure. A down to earth example comes from **Helsinki**. The ground gets more and more crowded with power and data cables, and with upcoming 5G, optical fibre will increase greatly. Foreseeing this future demand and the city's own future needs, Helsinki has started to install protective tubes and micro-channel piping for optical fibres, with massive capacity left for future use.

In case your city is at the start of the transformation towards LED with the ambition to go into Smart Lighting at a later stage, the future proof strategy of Budapest may be inspirational. **Budapest** selected LED luminaires equipped with NEMA sockets, as a first step in its street light renewal project, even though power consumption measurement was not yet implemented. NEMA sockets (Zhaga is comparable) provide the possibility to add dimming and motion control modules later. When the city is ready, and power measurement is applied, it can have the functional Smart NEMA modules installed without having to open the luminaires. This saves installation costs and keeps warranty periods intact.

LARGER SCALE ECONOMICS

Macro-economic factors also play a role in decisions and opportunities around Smart Lighting. In South Korea, Payback Period is longer than in other countries due to very low energy costs. Still, the government is investing 26bln KRW (19M Euro) from 2019-2023 to develop a Smart Street Lighting Integrated Platform and related pilot studies, to offer its domestic industry a chance to become a front runner in Smart City technology and applications[51]. This broader view is relevant also in EU cases, and emphasises the need to also look beyond the city level.

2.2

Organising expertise

A certain level of knowledge of ICT elements of Smart Lighting such as advanced controls, communication protocols, and data management, needs to be present within the municipality to be able to initiate, steer and maintain Smart Lighting projects

LIGHTING SYSTEMS HAVE historically been part of the Electrical Engineering domain. There is however a clear shift towards the ICT domain, with lights and sensors becoming nodes in an IT network, communicating data via IT protocols. As a result, specifying, using and maintaining lighting requires ever more ICT skills. A certain level of knowledge of ICT elements of Smart Lighting such as advanced controls, communication protocols, and data management, needs to be present within the municipality to be able to initiate, steer and maintain Smart Lighting projects[52]. Assessing offers from industry, collaborating with external partners, drafting contracts: all this requires general ICT domain knowledge. This knowledge is not always available or within reach.

However, ICT skills alone are not enough. Smart Lighting cannot be reduced to Internet of Things technology. Domain knowledge of lighting is essential to make the right decisions. Next to that, Smart Lighting is a significant lighting design challenge, given the wide range of human implications. All these kinds of expertise need to come together. We treat a number of possible ways to organize the necessary expertise:

- For larger municipalities, it may be worthwhile to set up a specialized department for the outdoor digital networks [Dans om de Paal, 2020 (Dutch)], especially when multiple 'verticals' are included in the city's ambition.

- If this is not feasible, seek ways to build up and share knowledge within the organisation. Having a city digital board, made up of internal experts, that educates operational managers about digital tools and shares digital tools between verticals could be an efficient way to improve[53]. Through regular contacts with the lighting people, joint knowledge can be built up over time.

- Alternatively, create an ecosystem with the city, external experts, advisors and suppliers to jointly build up knowledge and skills. An example is the Urban Development Initiative in the Dutch Brainport region[54].

Creating successful Smart Lighting applications for citizens requires design expertise

Note that organising external expertise is useful, but internal lighting people will also inevitably need to get more acquainted with ICT and Internet of Things (IoT) concepts so that they can communicate with experts and suppliers in those fields, and stay in the lead regarding the subject of lighting. Lighting should take and keep leadership in Smart Lighting. There is a philosophy behind lighting that incorporates both technology and specific interests of citizens in public space. ICT alone does not cover this heterogeneous field and thus has insufficient scope to run a Smart Lighting project.

Education is essential in a fast-moving area like Smart Lighting. Examples exist of compact and more elaborate courses focusing on Smart Lighting. The Korea Institute of Lighting & ICT offers a 6-day Smart Lighting course[55] and professional education programs are available at academic institutes, such as the multidisciplinary continuing education program of lighting design at University of Oulu, Finland[56].

DESIGN EXPERTISE

Creating successful Smart Lighting applications for citizens requires design expertise: such human-oriented applications cannot just be installed or engineered. They need a design process, led by a design professional or design team. Designers are trained to employ technologies to enable valuable human experiences, balancing a wide range of technical and human-related criteria, and master techniques to involve citizens and other stakeholders in the process.

The interactive and multi-disciplinary nature of Smart Lighting is extending the scope of public lighting design. Multi-disciplinary

design teams, encompassing expertise as varied as interaction design, urban planning, data enabled design and policy creation alongside lighting design may become ever more common in the field of Smart Lighting design.

2.3 Conducting a pilot

PILOTS ARE GENERALLY considered positive vehicles to start up Smart Lighting. They offer intense learning-by-doing opportunities that bring up a multitude of issues to tackle on a still manageable scale. They help test operations and functionality (e.g. interoperability, the management system and security issues), help define and evaluate lighting quality (e.g. light levels and colour temperature, form factors and hardware) and help create citizen engagement[57]. Furthermore, the tangible results facilitate communication and decision-making around Smart Lighting.

There is no fixed recipe for conducting a pilot, but we can benefit from insights from other cities' pilots:

- **Set up your pilot in a future proof way:** Do not see it as an isolated activity, but as a step towards subsequent, larger projects, even if these are not planned yet. For example, when you choose a technical infrastructure that is open and interoperable for your pilot, it will be easier to expand on it later and to apply it in different projects.
- **Use pilots to build a network:** One insight is that pilots are excellent opportunities for creating or developing an eco-system of partners, including the municipality, industry, knowledge institutes and the citizen community. Such an ecology of partners is considered beneficial for the chance of success of a project, and once established it can benefit follow-up projects as well.
- **Allow flexibility:** The results and implications of a pilot can never be fully predicted. Citizens may respond differently than anticipated and unexpected technical issues most likely will occur. But unexpected benefits may also surface along the way. Trying to prevent all risks upfront decreases the pilot's flexibility to respond to unexpected events. So building in some flexibility is recommended, however difficult given the underlying formal processes.
- **Reflect on the pilot:** Pilots run the risk of remaining isolated one-offs. Create reflection and knowledge transfer mechanisms so that the next activity can build on the previous one. Embedding a pilot in a long-term roadmap gives a clear framework for reflection and helps to build further on the pilot's results.
- **Learn from the pilots of other cities:** Larger projects like SMART-SPACE and LUCIA have documented lessons from multiple pilots[58] [59]. LUCI offers a Knowledge Hub for members that brings these results together and offers a platform to contact the people involved for direct knowledge exchange.
- Lastly, **pilots can help attract public funding** in case their goals align with regional, national or international aims. There are many examples of pilots that benefit from EU or national funding schemes. In this way, they help overcome a financial threshold and kick-start a city's Smart Lighting ambition.

Choose a technical infrastructure that is open and interoperable for your pilot, it will be easier to expand on it later

Citizens create and discuss self-made light scenes in their own neighbourhood during a 'Light Sketching' session in Eindhoven [Ross & Kalinauskaite, 2020, p. 16-19]. Image: Bart van Overbeeke

2.4

Engaging citizens

Wherever possible, citizens should have a say in processes that impact their daily lives. New forms of participation should be encouraged and improved, including co-creation and co-design in cooperation with inhabitants, civil society networks, community organisations and private enterprises. [Leipzig 2020 New Charter on Sustainable European Cities]

"ENGAGE WITH THE community now, or redo your project later". We should take this warning from an experienced expert seriously. Smart Lighting affects public space, for example when it decides to dim down the light in certain circumstances or when it gathers data about activities. Such apparently straightforward applications can have significant consequences for citizens. And a new use of data from an existing system can cause serious protest[60]. Involving citizens in designing, assessing and adjusting Smart Lighting systems can help avoid problems and missed opportunities.

A Nighttime Exploratory Walk with citizens in Neuchatel, Switzerland. Image courtesy Radiance35

Involving citizens in designing, assessing and adjusting Smart Lighting systems can help avoid problems and missed opportunities

Citizens' local knowledge is a rich resource, worthy to consider as expertise. But public lighting is generally a low engagement topic for citizens. For many, it is just there or it is broken. This is however likely to change, because of growing awareness of the ecological impact of light, but also because of visible changes due to LEDification, dynamic dimming, changes in lighting colour temperatures and visual emergence of smart poles.

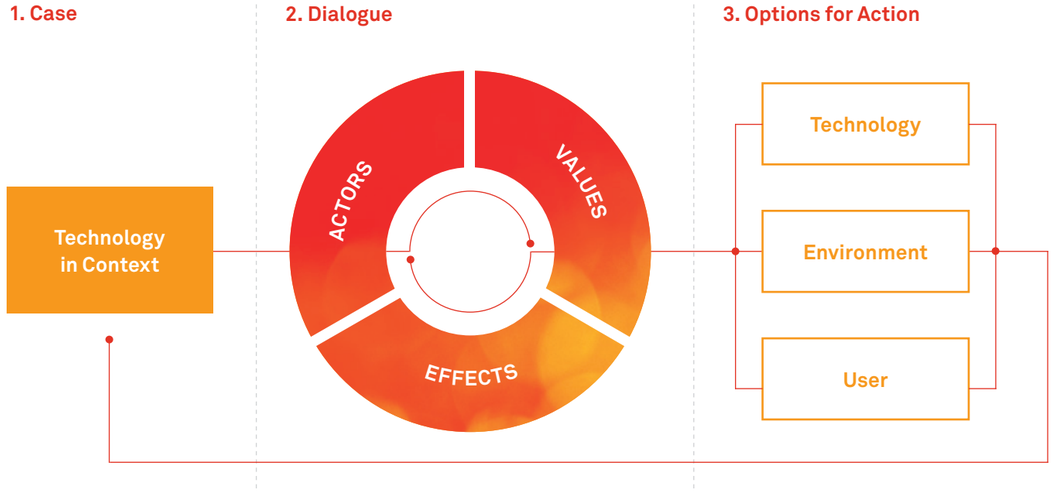
"First level operators", such as shopkeepers, bar-owners, police officers, street cleaners, commuters, etc., should also be considered in the scope. They form an important segment of society and have their own use of public space at night and ideas about it. How can we involve citizens and other stakeholders?

TECHNIQUES AND APPROACHES

Several techniques exist to gather insights from citizens for Smart Lighting projects, for example:

- Night walks in which people "are invited to show relevant places and situations that can be investigated at the spot. Environment and context support an in-depth discussion on both the problem and potential solutions for the situation"[61].
- A wide range of co-creation techniques that enable citizens to give creative input into a project. Examples are Use Case Workshops[62], NightSeeing™ [63], Night-time Exploratory Walks[64] and Light Sketching[65].
- The Dutch city of Rotterdam conducted surveys to compare residents' experience of regular and detection-based dimming schemes in the Bredenoord area. The results gave confidence that adaptive dimming, with its large energy saving potential, was accepted by residents and did not compromise their feeling of safety.
- Prototyping an envisioned system, bringing it into citizens' experience, is a way to create engagement and gain input. Prototyping can be done in many ways, ranging from small light set-ups in the city to a digital twin in virtual reality.

GUIDANCE ETHICS APPROACH



The three step, iterative process of the Guidance Ethics approach, adapted from [Verbeek & Tijink, 2020]

→ 'Guidance Ethics' is a promising approach to incorporate ethical implications for citizens in the development, realisation and operation of a technical system like Smart Lighting. It offers concrete steps that help understand the technology, support dialogue about its application and facilitate decision-making about actions together with the relevant actors[66]. An important lesson from this approach is that involvement of citizens should not end after a system is realised. Needs change over time and new applications may emerge on the existing infrastructure, requiring ongoing feedback loops with citizens and other relevant parties.

Note that there is a fundamental difference between citizens and professionals that must be considered in joint activities. Citizens only have their spare time to spend, they have no professional background in lighting and they have a different legal position. This needs to be considered in deciding on ways of involvement and distribution of responsibilities.

SHARING DATA

Sharing data with citizens, in a responsible manner, is a way to create a more symmetrical relation between the city that owns the data-gathering infrastructure and its citizens that generate data. There are several good resources to help set this up, e.g. Data.Europa.eu[67].

Data is a complex topic, both for city professionals and citizens. Learning about the implications of data gathering and usage in public space is an ongoing process that requires cities and citizens to learn from each other. Cities need to explain their plans and activities related to data in public space to citizens, which helps citizens participate in political decision-making around Smart Lighting. At the same time, citizens can inform cities about the implications of data in their daily life, and point towards issues and new potential. The key is that it is a mutual learning process.

2.5

Ensuring interoperability

"Use a commonly agreed list of standards and technical specifications to achieve interoperability of data, systems, and platforms among cities and communities and suppliers around the world;" [Join Boost Sustain EU]

ENSURING INTEROPERABILITY is considered a key issue in Smart Lighting[68]. There are many vendors, platforms, communication protocols, and the market is developing quickly. Although large private vendors offer systems with broad functionality, systems from different suppliers generally do not work together.

Cities worry about vendor lock-ins and the (future) availability of components that can function with their existing infrastructure. Cities are hesitant to become dependent on a single supplier for a strategic domain with fast technological and market developments. Using a single supplier can have advantages, but becomes problematic in case of a lock-in. This could even hamper a city's autonomy in the long run. Being flexible in terms of the solutions used is part of being a future-proof city.

Being flexible in terms of the solutions used is part of being a future-proof city

Interoperability and ways to deal with it

The concept of interoperability comes into play in different levels:

- **Network layer:** Simply put this is about the carrier of the communication between devices. Examples for outdoor applications are LoRaWan (Long Range Wide Area Network) and NB-IoT (Narrowband Internet of Things). This layer is comparable with WiFi or 4G in the consumer electronics world. Devices in the home can share data via these means. It is however not enough for interoperability. A smart refrigerator with WiFi connection does not automatically communicate meaningfully with a connected doorbell, just because they are on the same WiFi network. They need a shared language as well. This happens at the software layer:
- **Software layer:** This is about devices understanding each other's messages, the content of their communication. You could compare this to the language that people speak to each other.
- **Hardware layer:** This layer contains all the physical devices in the system to make it work. For example, the Smart streetlights and environmental sensors in a Smart Lighting system.

(See figure 1)

Until recently, there was no open and royalty-free software standard for such a common communication language in street lighting. But this is changing. Industrial alliances are emerging to solve this issue. They work at different levels, but in synergy with each other.

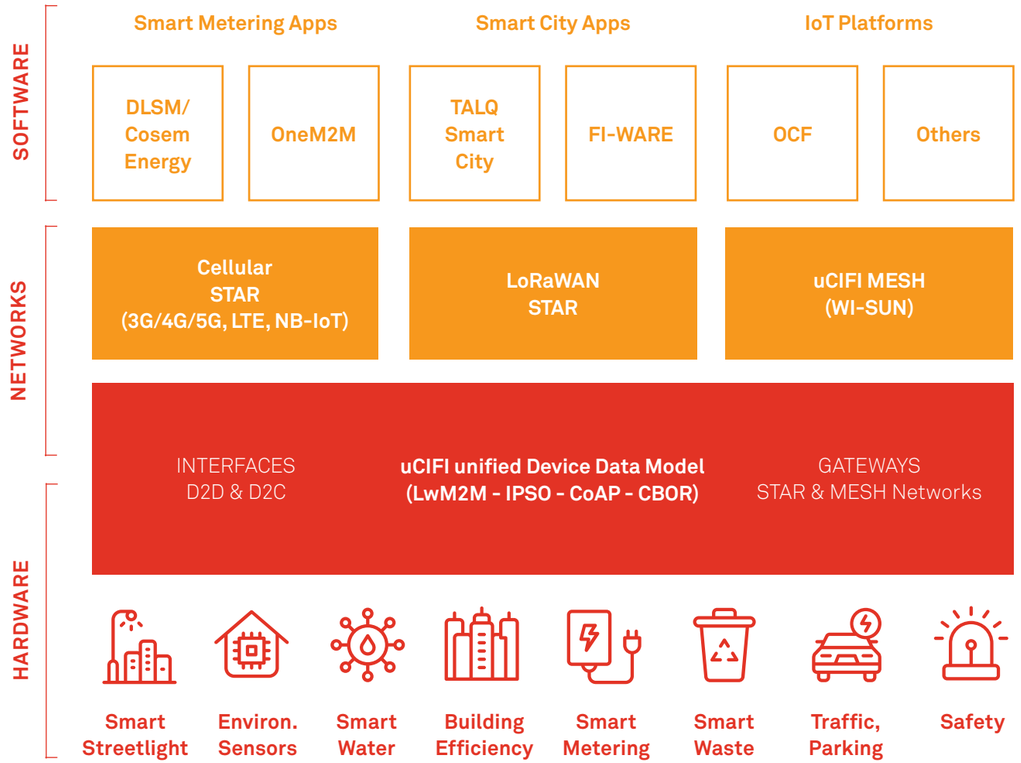
Firstly, an industry consortium like TALQ[69] offers a commonly agreed internet language that allows city management software to communicate to Gateways from different suppliers. (A Gateway groups multiple devices, like street lights and handles communication to other systems, like a city's resource management software).

Secondly, an alliance like uCIFI[70] offers an open and unified data model for devices to communicate with a common 'data language' on the network. uCIFI enables interoperability in terms of devices and network. This allows connected devices of one vendor to be replaced by an equivalent device of another plug-and-play.

Thirdly, an industry standard like Zhaga or NEMA offers a standardised connector to the luminaire. This allows the connection of sensors from different suppliers to the LED luminaire.

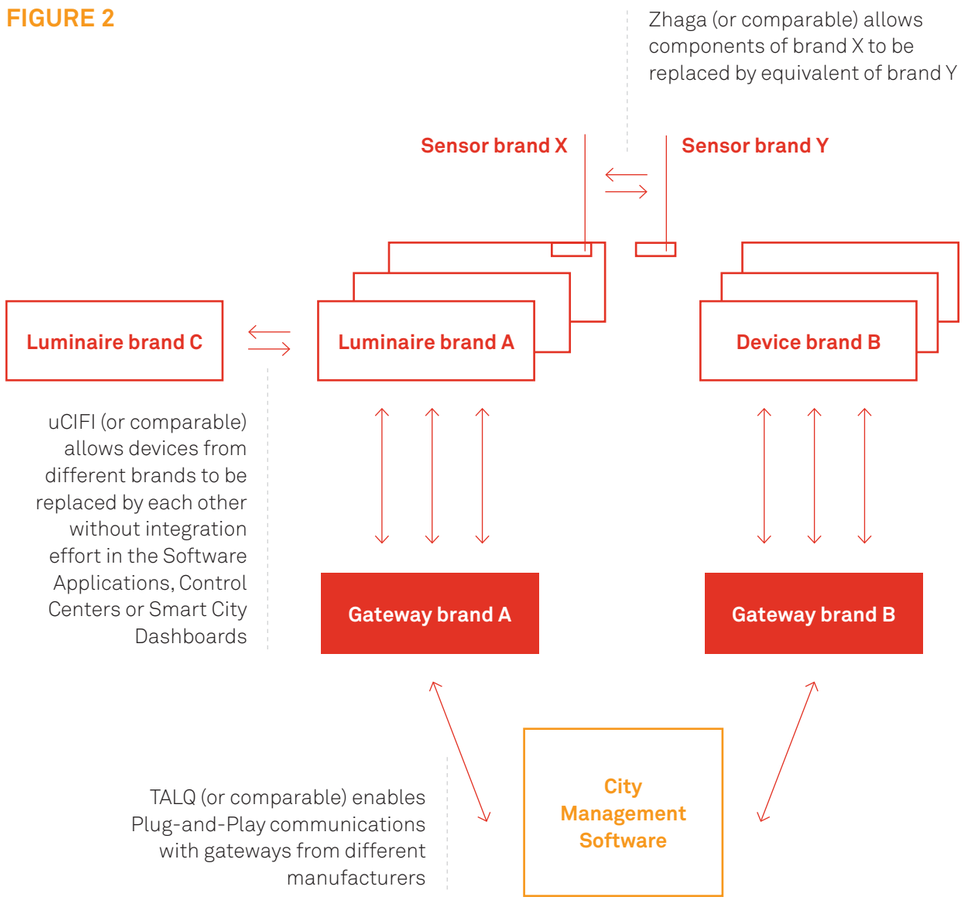
(See figure 2)

FIGURE 1



Overview of different layers relevant to interoperability. Image adapted from uCIFI Alliance [https://ucifi.org]

FIGURE 2



Using open standards allows flexibility to replace parts of the system with equivalents irrespective of vendor

Using open standards (see the box) allows flexibility to replace parts of the system with equivalents irrespective of vendor. It also reduces the need to program specific software to make one system talk to another (e.g. via Application Programming Interfaces or API's). This saves costs and time.

An additional benefit of data models like TALQ and uCIFI (see the box) is that they also incorporate devices from other Smart City applications, such as energy metering, air quality sensing, waste management, parking and mobility, making synergy with other Smart City applications easier to achieve. Next to that, it gives the opportunity for smaller, local companies to create compatible Smart Lighting applications. Reduced fear of vendor lock-in on the demand side could also benefit larger vendors, since the total market size can increase significantly.

2.6 Tendering

'Use common public procurement practices to jointly define specifications & reduce cost of investing in successful digital platforms & related technologies.' [Join Boost Sustain EU]

WE BELIEVE IN the power of cities to make a difference when working together. Tendering is a powerful tool that cities have to help move the Smart Lighting industry forward in a direction that lowers the threshold for entering and safeguards a city's flexibility.

TENDERING FOR INTEROPERABILITY

Many cities share the question of what to write in tenders to avoid vendor lock-in and ensure interoperability of system components now and in future. Open and royalty free standards that enable interoperability on different levels are emerging, as described in the previous section. But industry does not automatically adopt open standards and interoperability. This is understandable from the individual vendor's perspective, but it presents a barrier for cities to step in, hesitant because of possible enduring vendor lock-in.

Cities have the power to create a breakthrough in widespread adoption of open standards and interoperable systems, simply by jointly demanding them in tenders. The gist of what to ask the market

Cities have the power to create a breakthrough in widespread adoption of open standards and interoperable systems

is simple: every device (controller, streetlight, gateway) in the Smart Lighting network should be replaceable with an equivalent device from a different brand and function plug and play with management software, even if this management software is not supplied by the hardware manufacturer. LUCI is in the process of collecting example tender texts to support cities in asking for interoperability.

TENDERING FOR SOCIAL SUSTAINABILITY

When a city values Social Sustainability in a Smart City project, it is worthwhile to include such values in the tendering process. In that way it becomes formally embedded in the activities of contributing market parties.

Adaptable lighting scenarios for a playground in Albertslund; image courtesy Lighting Metropolis © Daily Snow Leth.

The **City of Albertslund**, for example, has required involvement of teachers and pupils in a tender for an interactive playground. The winning company had described how it would facilitate a workshop with the pupils to determine the "theme" of the lighting and how they would approach user involvement in general. On a larger scale, in 2016, Alberslund set up a citizen group of 42 "lighting ambassadors" to involve citizens in the decision-making process around modernisation of urban lighting. For each residential area they discussed the payment model, luminaire selection, dimming, roll-out strategy, development and innovation projects, and Smart City elements. These citizen insights were incorporated in the tenders. They also led to a framework agreement that gave citizens a say in the further implementation of the projects.

Of course, Social Sustainability is broader than the citizen engagement in these examples, but it shows that this kind of topic can become part of a tendering strategy.

2.7

Data Management

Data should be used for the common good, with ethical and socially responsible access, use, sharing and management. At the same time, this data usage should be carefully weighed against privacy issues. [Leipzig 2020 New Charter on Sustainable European Cities]

DATA MANAGEMENT SHOULD be part of any Smart Lighting initiative or strategy. There is first of all an applicable legal framework: The General Data Protection Regulation (GDPR), regulating how citizens' data should be protected. Note that this is EU specific: other continents or countries will have different laws.

Some data from a Smart Lighting system are not considered personal, such as lamp internal temperatures. Some data are clearly personal, such as video feeds of cameras. But many types of data are not so clear-cut personal or non-personal. According to the GDPR, 'personal data are any information which are related to an identified or identifiable natural person.'

Even data that does not directly identify a person should still be considered personal when it can contribute to identifying a person in combination with other data. Especially when operating in public space, which people cannot avoid, one must be alert in deciding which data to gather and which not to, and adhere to the GDPR framework. Recently a municipality in the Netherlands was fined €600k by the Dutch Data Protection Authority for its use of Wi-Fi sensors to measure the number of people in the city centre. The fine was based on the fact that such sensing *could* be used for people tracking, even though it was not used for that purpose[71].
GDPR sets the boundary conditions for data management, but the EUROCITIES principles on citizen data[72] go a step further and formulate a citizen driven vision on data. Their aim is "to give guidance to European local governments on how to use data-generated knowledge to improve urban life and preserve European values through scientific, civic, social, economic and democratic progress. This includes putting in place mechanisms and practices to give citizens control over their data."

They define citizen data as follows: "Citizen data is personal and non-personal data, directly or indirectly generated in the digital public

Once we agree that this data is citizen data, we should see it as a public asset and use it solely in the public interest

sphere, using digital technologies and collected through different infrastructures [...]. This data is traced, collected, measured, stored, used, managed and processed both by public and private entities (according to the General Data Protection Regulation)."

This definition of citizen data is highly relevant to data gathered by Smart Lighting systems. Once we agree that this data is citizen data, we should see it as a public asset and use it solely in the public interest. Note that the topic of interoperability also applies here: if data is closed and in proprietary (vendor specific) formats, sharing and responsible re-use becomes hard or impossible.

Safeguards should be put in place to avoid the risk of identifying individuals through existing or new data analysis technologies. It should be clear that this is an ongoing effort that requires ample resources. There are multiple guides and examples on applying an open data vision in practice. See for example the Open Data and Privacy report from the European Data Portal [Data.Europa.eu] and Data People Cities, Eurocities Citizen Data Principles In Action[73]. These are not specifically directed at Smart Lighting, but still relevant.

CYBERSECURITY

The transformation of lighting infrastructure into Internet of Things (IoT) networks, brings in the security threats that these kinds of networks inherently introduce. It is not difficult to imagine the damage inflicted on a city and its citizens when a public Smart Lighting network is hacked and compromised. This topic is not limited to Smart Lighting. It is central to the overall digitisation of cities, and it is therefore beyond the scope of this paper to go into detail about this topic. But it should be a priority in every stage of a Smart Lighting initiative.

3. Helpful resources

Policy Documents

- **LUCI Charter**: The LUCI Charter on Urban Lighting aims to bring cities together around common principles in lighting and to mark the network's commitment to sustainable development. It has been signed by over 60 cities worldwide, since 2010.
- **New Leipzig Charter on Sustainable European Cities**: "The New Leipzig Charter provides a key policy framework document for sustainable urban development in Europe. The Charter highlights that cities need to establish integrated and sustainable urban development strategies and ensure their implementation for the city as a whole, from its functional areas to its neighbourhoods. [...] Member States agreed to implement the Charter in their national or regional urban policies."
- **Eurocities Principles on Citizen Data**: "The principles recognise, protect and uphold the citizens' rights on the data they produce. They cover issues of ownership, control, privacy, transparency and accountability, quality, interoperability and social responsibility."

Smart Lighting

- **LUCIA Compendium**: A compact summary of the findings, recommendations, and tools that have been identified and created during the first phase of the Interreg BSR project LUCIA on sustainable and smart urban lighting. The LUCIA factsheets, available on the LUCIA website address separate topics, like finance and economics.
- **SMART-SPACE**: This Interreg NWE project delivered a number of helpful documents, with topics ranging from Smart Lighting applications to technological desk studies.
- **Municipal Smart City Street Light Conversion Guidebook**: A guide for municipalities considering converting to LED street lights & Smart City technologies. Written for the US context, but interesting for other regions as well.
- **LUCI Hub**: Urban lighting knowledge and networking online platform, accessible to LUCI members.

Smart City related

- **Smart Cities Marketplace**: A community site of the EU that aims to bring cities, industries, SMEs, investors, researchers and other smart city actors together around the topic of Smart Cities.
- **Smart City Guidance Package**: The Smart City Guidance Package aims to help cities to plan and implement smart city projects.
- **Eindhoven Smart Society Iot Charter**: A concisely formulated set of principles for architectures of Internet of Things initiatives in the city, also adopted by several other cities.

Data Management & Citizen Engagement

- **https://data.europa.eu/en**: An EU platform with guides, examples, and directives on Open Data.
- **Guidance Ethics Approach**: A practical action guide to incorporate moral considerations in the development of new technological applications in an iterative process involving multiple parties.

Abbreviations

- **API**: Application Programming Interface, a software connection that allows software from different devices to work together.
- **GDPR**: General Data Protection Regulation. European regulation that harmonises all data privacy laws across Europe.
- **IoT**: Internet of Things, the network of devices ('things') that connect to each other and exchange data via the Internet.
- **5G**: Fifth generation of cellular network technology, used to transfer data wirelessly at high speeds. 5G is faster than 4G, but needs more closely spaced antennas to function.

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About LUCI

LUCI (Lighting Urban Community International) is the international network of cities on urban lighting. Created in 2002 at the initiative of the City of Lyon, today, LUCI is a non-profit organisation bringing together over 70 member towns and cities worldwide that use light as a tool for social, cultural and economic development. It also includes over 50 associated members from the lighting industry, design agencies and research institutes.Through the organisation of international events and conferences, and by piloting lighting projects and research initiatives, LUCI supports city-to-city collaboration and peer-to-peer exchanges, helping cities harness the potential of light to create sustainable and people-focused urban spaces.

luciassociation.org

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