LUCIA

LIGHTING THE BALTIC SEA REGION

LUCIA COMPENDIUM vol. 2

Deployment of Sustainable and Smart Urban Lighting

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LUCIA COMPENDIUM vol. 2

Deployment of Sustainable and Smart Urban Lighting

Tallinn University of Technology
Ehitajate tee 5, 19086 Tallinn, Estonia
Tel. +372 620 2002, Fax +372 620 2020
info@taltech.ee

Contact person:
Tarmo Korõtko, tarmo.korotko@taltech.ee
Tel. +372 522 1510

Editors:
Tarmo Korõtko, tarmo.korotko@taltech.ee
Yannick Le Moullec, yannick.lemoullec@taltech.ee

Authors:
Tarmo Korõtko, tarmo.korotko@taltech.ee
Heike Bunte, heike.bunte@altona.hamburg.de
Eva Tallo, eva.tallo@tallinnlv.ee
Ieva Šponberga, ieva.sponberga@jurmala.lv
Yolanda Potrykus, yolanda.potrykus@porvoo.fi
Yury Nurulin, yury.nurulin@gmail.com
Teddy Sibbern Axelsen, teddy.sibbern.axelsen@webuilddenmark.dk

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TAL TECH

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Introduction

The project LUCIA helps municipalities unlock their savings potential by providing public authorities with profound and up-to-date knowledge of state-of-the-art energy-efficient urban lighting, covering aspects of environment and technology, economics, and social acceptance. Since the mentioned approaches must be embedded into the urban planning context, up-to-date information on urban planning and procurement was provided for target groups – public authorities. LUCIA showed the potential of innovative energy-efficient lighting solutions in 6 pilot sites where energy-efficient lighting solutions were installed.

DOLL (Albertslund)

Hamburg Altona

Jurmala

Porvoo

St. Petersburg

Tallinn

Figure 1. Pilot sites of the project LUCIA – Lighting the Baltic Sea Region (top-left photo provided by DOLL Living Lab; top-middle photo provided by Bezirksamt Altona; top-right photo provided by Jurmala City Administration; bottom-left photo by Tarmo Korõtko, bottom-middle photo provided by SPbPU, bottom-right photo by Tarmo Korõtko).

The duration of project LUCIA ranged from January 2019 until September 2021. The total project budget was € 3.12 million, from which € 2.17 million was provided by the European Regional Development Fund and € 0.28 million from the European Neighbourhood Instrument and Russian funding. LUCIA brings together 11 partners from seven Baltic Sea region countries. The partnership consists of municipal and regional public authorities and expert partners. While expert partners provide state-of-the-art information on energy-efficient urban lighting and advise the participating municipalities, the municipal and regional actors run pilot sites in six municipalities and replicate the project results in their region.

A cornerstone of the project was the dissemination of knowledge and results to urban planners, energy and city lighting managers, and decision-makers in the BSR countries. The project included numerous regional and international events. The replication potential of suggested solutions was evaluated with pilot sites in the metropolitan regions of Hamburg, Tallinn, Riga, Helsinki, Greater Copenhagen (Albertslund), and St. Petersburg. Additionally, the online urban lighting knowledge centre was established, where all project results were published, and a network for city lighting managers was established.

The LUCIA project has disseminated knowledge and implemented energy-efficient lighting solutions in practice to change the planning procedures and select better urban lighting solutions. The first volume of the LUCIA Compendium covered the motivation for deploying sustainable and smart urban lighting solutions, highlighting the benefits in terms of people satisfaction, energy savings, environmental protection, business development, smart lighting technologies, economic aspects, tendering processes, societal acceptance, and how to integrate all the above into an actionable plan [1]. Decision-makers can now be more aware of energy-efficient lighting solutions and prefer such investments.

The pilot cases shall serve as beacon projects in the BSR, which can be visited and replicated in other cities in the BSR. This way, LUCIA contributes to climate mitigation efforts in the region. The second volume of the LUCIA compendium aims to give non-technical information about the pilot sites. Each pilot site's planning and implementation procedures are described to provide a holistic approach towards sustainable urban lighting and other critical aspects of the project LUCIA. An emphasis is put on individual experiences of municipalities, the use and relevance of green public procurement (GPP) guidelines, and formulating key performance indicators (KPI) to evaluate the provided improvements.

Figure 2. LUCIA pilot sites.

Mayors of different cities in the Baltic Sea Region provide their insights on Smart Urban Lighting

"Parks are becoming increasingly more important in urban landscapes. Green areas allow for rest and recreation of the mind, while plants in an urban setting improve the environment.

Parks are naturally beautiful in daylight; however, park lamps enable different details and nuances to be brought to the fore after sunset. Today, park lighting delivers more than mere functional solutions – providing direction, leading the way, and ensuring safety – and contributes to valuing of nature and the environment, helps create a memorable atmosphere, and comes in handy in displaying urban art.

All innovative cities are investing in developing energy-efficient LED-lighting; still, project LUCIA has significantly supplemented the added value of urban lighting, next to energy savings and technical knowledge highlighting multifunctional solutions, the need to establish lighting hierarchies, and the importance of protecting biological diversity and the night sky. Tallinn's pilot areas within the framework of project LUCIA include parks in the green belt surrounding the Old Town and reconstruction of lighting in Kanut Garden.

Lighting in said areas must consider both the milieu-valuable nature of Tallinn's medieval Old Town and the natural environment of the parks.

Establishment of lighting solutions must involve a variety of people as lighting that considers the individual and the environment is indeed our future. To better consult the interests of different target groups, we implemented comprehensive inclusion activities. The lighting solution prepared for Kanut Garden is the result of this inclusive approach that considers both the wishes of Tallinnites and recommendations of professional lighting designers."

Mihhail Kõlvart, Mayor of Tallinn

"The Lucia investment is implemented with the people first ideology. This means that different user groups have been taken into account in the designing of the park and lighting solutions. Cyclists, pedestrians, visually impaired people, tourists as well as residents are welcome to enjoy the high-quality urban park.

The new park where the Lucia pilot site is located connects different parts of the city. The new areas on the western side of the Porvoo river, the city centre and the old town are better connected to each other than before.

The Lucia project enables experimentation of new lighting technology and infrastructure and helps the city to evaluate and decide how to implement urban lighting investments in other locations in the future."

Fredrick von Schoultz, Deputy Mayor of the City of Porvoo

"Within the European LUCIA project we learned a lot from each other in terms of light pollution and saving energy which is essential to contribute to the welfare of residents and inhabitants in our district of Altona. Good examples and best practice from the LUCIA BSR Partner and regions change (active) mobility behaviour – also during dark hours – and make our public spaces safer. Environmental protection of rare species on the one hand and support of safe cycling and walking during dark hours on the other hand seemed to be a contradiction at the beginning of the project. The LUCIA project has shown new opportunities and options and bridged the gap successfully between these different interests. One key aspect on our way to bridging the gap was co-creation, the triad of involving our citizens, experts and experienced practitioners. This worked very well and we are looking forward to the next projects!"

Dr. Stefanie von Berg, Mayor, Borough of Altona

1 Supporting technologies to enable sustainable urban lighting (Albertslund, Denmark)

The City of Albertslund is placed in the suburb area of the Danish capital, Copenhagen. It is located 15 kilometres west of central Copenhagen, with around 30,000 residents. Albertslund is a planned community or town mainly built in the 1960s and 1970s. The suburb is known for its experimental and innovative low-rise urban planning, integrating water and green spaces in the architecture.[1]

While refurbishing its outdoor lighting infrastructure in 2014, the city of Albertslund established a living lab: the Danish Outdoor Lighting Lab (DOLL), for intelligent street lighting. The town has a strong tradition with outdoor lighting, having the 'Albertslund Lamp' named after the city, having chaired the international lighting network LUCI and being a core driver of the Greater Copenhagen-based Lighting Metropolis initiative.

Figure 3. City of Albertslund, Denmark.[2]

1 https://en.wikipedia.org/wiki/Albertslund
2 By Champ2100 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=64520225

DOLL has developed an innovative playground for new complex markets that demonstrate and test the latest solutions in intelligent outdoor lighting and Smart City services. The newly introduced LED technology has been a critical driver for showcasing many intelligent outdoor lighting solutions to address essential aspects such as quality, lighting distribution, glare, light management and profiles, energy efficiency, etc.

Figure 4. Danish Outdoor Living Lab (DOLL) in Albertslund, Denmark, at the outskirts of Copenhagen.[3]

Today, DOLL Living Lab is Europe's most extensive living lab encompassing 13 kilometres of different state-of-the-art solutions on the scale of 1:1. A dynamic ecosystem of industry and knowledge partners is continuously building and upgrading solutions across the area. A vital aspect of the DOLL Living Lab is to facilitate an international visitor service that has welcomed more than 500 delegations from around the globe.

The Lucia pilot area in Albertslund is located at DOLL Living Lab. Using DOLL as the pilot site in Denmark makes the project feasible for communication and scaling. The equipment selection and installation were conducted closely with companies innovating in intelligent, sustainable lighting.

3 https://www.google.com/maps

Figure 5. Luminaires from the DOLL living lab (all photos by Nicolai Perjesi).

1.1 Albertslund pilot site of project LUCIA

The LUCIA pilot site in DOLL in Albertslund was about replacing and upgrading 50 existing lighting points and equipping them with motion detection technologies. Together with existing installations, the new lighting points make a connected route through the DOLL Living Lab and create the basis for cohesive analysis and presentation of the possibilities in activity-based lighting solutions on the market. The activities included technical planning and surveillance of the installations and the installation of new traffic control signals (in two sites) and motion sensors (in 15 locations). It was desired that the solutions with motion sensors caould be integrated into the existing light management systems (LMS).

1.1.1 Planning

The municipality identified four more relevant aspects they wanted to focus on in the planning phase. The specified aspects were energy efficiency, economic aspects, the increase of system reliability, and the implementation of multi-functional technology (see Table 1). Once the aim of the pilot site was clarified, it was used to guide the planning and budgeting process.

TABLE 1. MORE RELEVANT ASPECTS FOR THE ALBERTSLUND PILOT SITE.

CRITERIA	DESCRIPTION
Energy efficiency	The optimization and reduction of energy consumption.
Economic reasoning	The purposeful use of resources for construction, maintenance, and utilization.
Reliability	The emphasis on technologies that are more reliable and increase reliability of the lighting system.
Multi functionality	The emphasis on equipment that enables the implementation of novel technology and creation of innovative services and revenue streams.

The LUCIA project assessed that requirements formulated as part of GPP guidelines must be less governing for the Albertslund pilot site since the starting point for focusing on a wide range of dynamic lighting solutions would naturally meet and align GPP guidelines. For example, requirements for energy efficiency are completed in the extreme sense due to the nature of the solutions that provide a minimum of light. In addition, the focus is not only on a single solution provider but a wide range of suppliers, which together present a significant selection of opportunities for cities to work with within the mentioned focus area.

1.1.2 Co-creation

Based on the Lighting Plan for Albertslund Municipality 2012 and Albertslund Municipality's action plan for replacing road lighting, a working group was set up in December 2016. The group aims to involve citizens in a democratic process around lighting modernization in residential areas. Topics to be processed were payment models, lamp selection, dimming, rollout strategy, development and innovation projects, Smart City elements, and marketing to citizens.

Together with the formation of the working group, a corps of 42 light ambassadors was established, involved in different processes. These are interested citizens, one from every residential area, which can contribute to lighting decisions in the municipality or be ambassadors for their residential area.

The choice of residential areas to be renovated is divided into 11 priority categories, based on age, technology, discontinued materials, energy consumption, etc. The aim is to complete the entire residential area when renovations have started and agree on lamp selection between adjacent/contiguous residential areas and through paths.

In the DOLL framework, an outdoor exhibition area was established to collaborate with the light ambassadors to determine the range of lamps for the residential areas. Subsequently, the exhibition area has been adapted for display and demonstration for the separate residential areas when choosing fixtures and solutions.

Figure 6. The DOLL centre in Albertslund, Denmark (photo by Jeppe Carlsen).

In addition to the luminaires, the exhibition also shows light masts at various heights, light control, dimming, and examples of intelligent measures such as motion sensors.

The individual residential areas can choose different lamps. It must be possible to choose between three to four lamp designs in each of the four categories: Road Lighting Fixtures, Park and Path Lighting Fixtures, Bollard Fixtures, and Wall Fixtures. The light ambassadors selected the lamps to be chosen after visits to the DOLL living lab day and evening. Light dimming and smart city options must be offered.

The roll-out of new lighting in residential areas occurs after consultations with residents and decisions at a general meeting. Before the public meeting, residents typically visit the exhibition area to determine which lamps are best for their location.

1.1.3 Market dialogue

With help from an associated consultancy service, a mapping of the market specialized within motion detection technologies and other supporting technologies related to the intelligent outdoor lighting industry was conducted. On this basis, invitations were made asking for interest in the project and to present the opportunity to participate in the LUCIA project concentrating on site-specific use-cases (solutions) at DOLL Living Lab for dynamic lighting as part of the outdoor lighting infrastructure.

Accordingly, market dialogues were conducted facilitated by the project team and the associated consultant. General material was prepared to guide the market dialogues, ensuring that all participants were presented for the same conditions and partly ensured that all elements were covered to elaborate on the exchanges [1].

The key to the selected approach was to ensure that suitable solutions were procured for each site. The vendors had the opportunity to visit one or more locations at DOLL. As a result, DOLL asked for 10–15 site-specific offers, thereby representing a row of solutions that could exist individually or in combination with others. The participating companies are listed in Table 2. Companies included in the market dialogue.

Read more about private and public development partnership

TABLE 2. COMPANIES INCLUDED IN THE MARKET DIALOGUE.

SEAS-NVE	Tridonic	Focus Lighting	Seneco
FutureAct	Novalume	Smartnodes	Comlight
Delux	Verdo	Swarco	Signify

Concludingly, the market dialogue process involved 12 different vendors, all of whom presented an offer to address intelligent, sustainable lighting as part of the DOLL Living Lab pilot site of project LUCIA.

1.1.4 Construction

Having conducted a bid-at-three approach, SEAS-NVE was appointed to perform the installation works at all sites. Several solutions were to be installed at various locations; thus, the installation company needed to be introduced to different technologies and pilot site areas early to comply with the right level of flexibility and know-how.

Some installations were carried out at the delivery of the equipment, but some unfortunate circumstances also introduced delays. For instance, the COVID-19 has enforced longer delivery times than anticipated. Nevertheless, the solutions across the sites have been completed appropriately.

Figure 7. Installation works at the LUCIA pilot site in Albertslund (all photos provided by DOLL Living Lab).

1.2 Pilot site evaluation

The aspects that were determined to be more relevant for the Albertslund pilot site were used to assess the success of the constructed pilot site. Based on the identified more pertinent aspects of the Albertslund pilot site, evaluation activities were carried out to evaluate the situation at the pilot site before and after the completion of the pilot project (see Table 3).

TABLE 3. EVALUATION OF MORE RELEVANT ASPECTS OF THE ALBERTSLUND PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Energy efficiency	A common denominator for the existing installations to be replaced was modern LED installations with fixed dimming profiles. Here, typical energy efficiency levels of 50% compared to the conventional non-LED-based lighting were achieved.	Sufficient lighting is provided only when activity is detected. That can be context-specific to, e.g., a bike, car, or pedestrian passing by or to a particular traffic scenario where the traffic's density on the road determines the level of light. Overall, the dynamic lighting installation increases energy efficiency by another 25-30% compared to the previous static LED installations.
Economic reasoning	Simple installation and maintenance. Typically, fixed lighting profiles only emphasize a traditional but somewhat efficient lighting installation.	The installation of dynamic lighting solutions does not significantly increase the complexity of the installation works. It is a plug-and-play installation, and once powered, the configuration can be done via a mobile application on-site. More sensitive components are added to the site, meaning that maintenance works between shorter intervals should be expected. The facility's utilization can meet context-specific needs to a much higher and more dynamic degree resulting in better lighting service offered to citizens and even wildlife.
Reliability	A high level of reliability is already achieved on the existing installations.	The use of the standards, such as the Zharga-sockets, and implementation of devices developed specifically to such standards increases the reliability significantly along with well-developed light management systems with optional asset management functionalities included.
Multi functionality	No direct multi-functionality is implemented.	Motion detection is based on different technologies or a combination of technologies that offer direct responsiveness adapting the lighting to the specific situation that increases, e.g., comfort, safety, and energy efficiency. In addition, information on the number of cars, bicyclists, or pedestrians is acquired, elevating urban planning opportunities and initiatives to a much more flexible degree as opposed to, e.g., annual counts only.

The used evaluation method and process regarding energy efficiency is mainly made with help from light management systems related to the individual solutions. Data is visualized and presented explaining the used energy or even direct energy savings compared to conventional lighting before the introduction of LED. The readings can vary across time and use; however, the average performance matches the numbers in the table above.

Read more about economic aspects of smart urban lighting

Regarding the economic reasoning, the method used relies on real-life experiences in connection with, e.g., actual installation work being made across all installations. Information from the LUCIA workshop [2] and documents about the economic impacts of smart urban lightning [3] provided valuable input in this assessment. Here, we followed the installation work and gathered on-site learnings and experiences shared by installation workers. Evaluation of maintenance is partly concluded based on previous learnings in the lab and input from the industry. No maintenance has yet been carried out within the project timeframe. The reliability of the solutions is evaluated throughout their operational lifetime.

The multi-functionality is evaluated partly based on the variety of solutions offered by the vendors and somewhat using practical experience. The array of equipment indicates the extent of multi-functionality adopted into lighting solutions' overall design. The knowledge gained by putting the technology into practice enables the assessment of its tangible effects. Experiences from co-creation activities were also included, where comfort, safety, and the use of multi-functionality were addressed.

Read more about expert workshops on the topic of economic aspects of smart urban lighting

It might seem straightforward at first that energy efficiency gains (an additional 25-30% when compared to existing LED-based street lighting with fixed lighting profiles) can be achieved by utilizing dynamic lighting installations. However, such installations and results depend highly on the context of dynamic lighting. Higher requirements are placed on the technology providers, consultants, and Municipality lighting professionals to ensure the most suitable solutions are optimally used. In short, more detailed knowledge of the specific use case is required.

Nonetheless, the offered multi-functionality provides much more flexible and dynamic use, increasing the opportunity for a significantly higher level of service to citizens and potentially also respecting wildlife to a much higher degree [4]. If installed and commissioned correctly, keeping a close eye on comfort and safety measures, the potential extra costs and maintenance work could be balanced.

Read more about supporting technologies that are the key to smart lighting

A virtual reality (VR) tool has been designed to emphasize utilizing lighting design parameters within a gaming environment to understand better and demonstrate the application areas of dynamic lighting solutions. The VR tool provides a unique environment for decision-makers to have a virtual experience of best applying the dynamic and multi-functionality aspects.

Moreover, the multi-functionality creates opportunities for merging the lighting infrastructure with the traffic light systems on a data level. At the DOLL Living Lab, data output from motion detection sensors is integrated with the traffic light control units to adjust the duration of green light for pedestrians.

Finally, it is of great importance that standards have now been introduced and adopted broadly across vendors and manufacturers. The standard Zhaga-socket creates significantly more reliability for the offered solutions and brings the lighting infrastructure a Smart City element that, in practice, has proven to be easy to use and connect.

1.3 Summary

The LUCIA Albertslund pilot site at the DOLL Living Lab has successfully been realized and completed. Through several solutions with different lighting and sensor companies, Europe's most ambitious collection of outdoor dynamic lighting solutions for the emerging smart and sustainable cities has been realized. The pilot site realization included collaboration with 12 players from different countries, providing state-of-the-art solutions for combining lighting, sensor, and light management technologies and solutions.

Together with the involved solution providers, a set of application areas for dynamic lighting have been outlined and demonstrated on the scale of 1:1 across roads and bicycle lanes at DOLL Living Lab. The pilot site includes solutions for pedestrians, bicyclists, and cars to either increase energy efficiency or provide an increased feeling of safety and comfort for a better and calmer traffic flow.

The pilot site realization has been completed in steps, where market dialogues have been conducted to find the most relevant providers of dynamic lighting solutions. Many players were invited to cover several sites at DOLL Living Lab. The installations were completed and evaluated at the later stages of the project.

With the help of standards and a convincing plug-and-play installation process, the installed solutions demonstrate a high level of maturity and reliability. An increasing amount of detail is required for intelligent lighting solutions' design and application analysis to exploit their full potential. The importance of lighting professionals, consultants, and public decision-makers is becoming more significant with the scaling of novel technologies for intelligent and sustainable urban lighting.

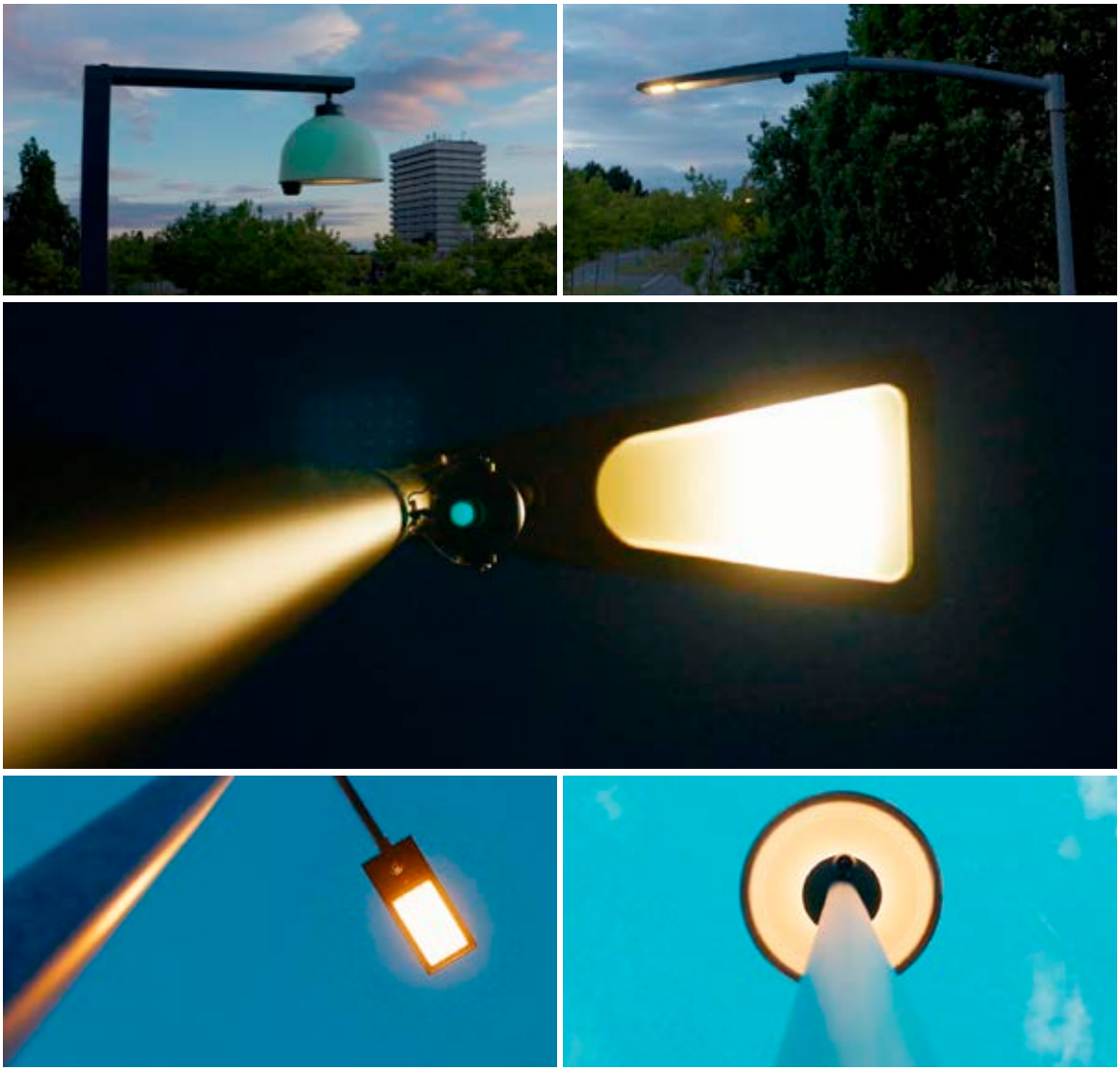


Figure 8. LUCIA Albertslund pilot site at DOLL Living Lab (all photos provided by DOLL Living Lab).

2 Public space in the field of tension between livability, active mobility, and the protection of species (Hamburg Altona, Germany)

The Free and Hanseatic City of Hamburg is the second-largest city in Germany after Berlin and the 7th largest city in the European Union. Hamburg's metropolitan area is home to more than five million people. The city lies on the River Elbe and two tributaries, the River Alster and the River Bille, and it is one of Germany's 16 federated states.[4]

Altona is the westernmost urban borough (Bezirk) of the German city-state of Hamburg, on the right bank of the Elbe River.[5] Once a thriving fishing town under Danish rule, Altona only became part of Hamburg in 1938. Altona-Altstadt and Altona-Nord, are popular residential neighbourhoods. Green and spacious Bahrenfeld is best known for one of the world's leading accelerator centres: Deutsches Elektronen-Synchrotron or DESY. Along the river Elbe lies the sub-urban Othmarschen with its famous Elbe River beach and Blankenese, known for its Treppenviertel and panoramic river views.

Figure 9. The Free and Hanseatic City of Hamburg and the district of Altona.[6]

4 https://en.wikipedia.org/wiki/Hamburg
5 https://en.wikipedia.org/wiki/Altona,_Hamburg
6 Imago stock & people / Hoch Zwei Stock / Angerer; https://www.hamburg.com/residents/neighbourhoods/11749766/altona/

2.1 Hamburg pilot site of project LUCIA

The LUCIA pilot site in Hamburg is situated along the famous "Elbewanderweg", a walking and cycling pathway along the river Elbe. Many inhabitants of Hamburg's borough of Altona know this area as a "green lung" for recreational activities.

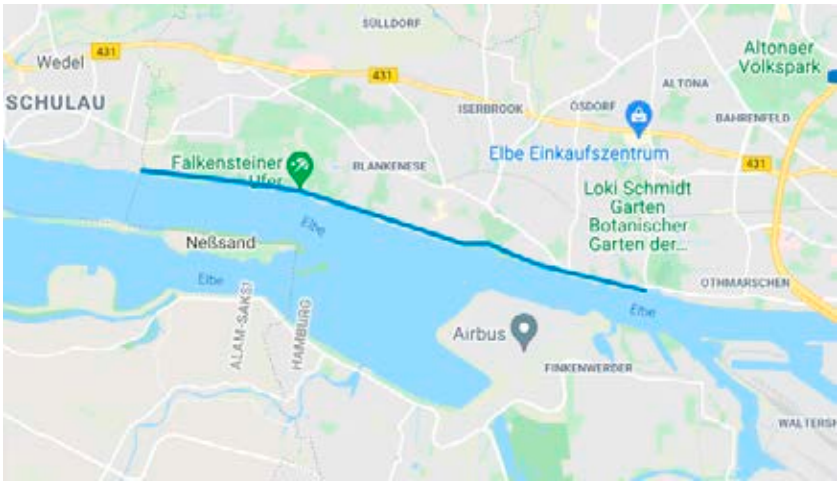


Figure 10. The "Elbewanderweg" is a central commuter route for cyclists and pedestrians along and across the river Elbe.[7]

This pathway is also a central commuter route for cyclists and pedestrians along and across the river Elbe to Hamburg-Finkenwerder and central Hamburg. There is no public lighting in certain parts of the project area. LUCIA wants to close these gaps and introduce a light art concept for a small pedestrian and cyclists' tunnel under the Elbchaussee street and new modern energy-efficient public lighting along with parts of the pathway.

Figure 11. Parts of the "Elbewanderweg" in Hamburg, Germany. Before project LUCIA, the pathway (left) lacked any street lighting, and the pedestrian tunnel was underexposed dark and covered with graffiti. (both photos by: Bezirksamt Altona).

7 https://www.google.com/maps

The pilot site is about 1,5 kilometres in length and averages around 4 meters in width, sealed with asphalt, adjacent to the waterfront, or in some parts a beach area. Additionally, the pilot site includes a narrow pedestrian and cyclist tunnel under the street "Elbchaussee" at the corner of "Elbschloßstraße." When used, the tunnel constitutes an unpleasant atmosphere due to its lack of proper lighting and overall scruffiness: stairs alongside the Elbewanderweg leading up to the main street areas of pre-LUCIA unilluminated.

During daily peak hours, more than 5,000 cyclists and pedestrians travel each direction from the public quay "Teufelsbrück" along and over the river Elbe appropriate lighting is inevitable. Therefore, the main goal is to close the gaps with public lighting along the pathway and sideways, e.g., tunnel and steps.

2.1.1 Planning

There are different aspects to lighting concepts and planning procedures overall. Varying emphasis on critical criteria is inherent. The Hamburg project team aimed to define 3 to 4 main elements, more relevant for their pilot site. These criteria were used to guide the planning, design, and implementation phase and serve as a tool for evaluating the constructed pilot site. As with the study site "Elbewanderweg" in Hamburg, the emphasis was mainly on protecting species, energy efficiency, monitoring and control systems, and public opinion (see Table 4). Those criteria serve as a red line and are essential to comprehend the choices made during planning. Furthermore, they convey the main ideas and goals regarding the pilot site and project overall.

TABLE 4. MORE RELEVANT ASPECTS FOR THE HAMBURG PILOT SITE.

CRITERIA	DESCRIPTION
Protection of species	The minimization of encroachments into habitats and possible threats to the natural flora and fauna.
Energy efficiency	The optimization and reduction of energy consumption.
Monitoring and control	The addition or improvement of monitoring and control systems or functions.
Public opinion	The increase of positive public opinion.

2.1.2 Co-creation

An essential criterion for the pilot site in Hamburg is public opinion and the acceptance of the newly designed segment. Co-creation events were held in different formats to give people an insight into the work and open a stage for discussions. These events included lighting walks with residents, special gatherings for the "Elbschlosstunnel", and a series of webinars with administration representatives, politicians, and NGOs from outside of Hamburg.

The lighting workshop and webinars exchanged with the target groups and provided valuable insights. The events held in small groups of 5 to 10 people resulted in intensive discussions on the topics addressed.

Restrictions related to the COVID-19 pandemic also influenced co-creation events, and the planned activities had to be revised accordingly. For example, the COVID-19 limitations limited group size for guided walks, which resulted in unproportionally high effort compared to impact. The discussions with those who decided to participate in guided walks

Read more from the LUCIA Co-creation reader "Co-creating Urban Lighting Solutions: LUCIA lessons learned report"

provided exciting perspectives and demonstrated interest in lighting issues among public members. It was concluded that the most significant impact of COVID-19 restrictions towards co-creation has been the lack of personal exchanges with citizens. [5]

Another co-creation activity was carried out in the form of an online survey. The survey did not generate the number of results that were expected. Only 14 persons completed the online poll, and three used the map-based tool. Given the availability of the survey (more than three months) and several attempts to promote the study, the results were not as good as expected. Several press releases and social media posts failed to produce the desired outcome. Given the above experience, we concluded that the lighting along the pathway is not perceived as an actionable problem.

2.1.3 Design

The redesigned Elbewanderweg features 29 new lamps along the trail itself as well as six new lamps placed inside the "Schröders Elbschlosstunnel." Not all lamp posts were utterly new; some had only a new head installed. When determining the procured lamps, various aspects of light pollution were considered, as ambient light controls circadian rhythms of living organisms and influences seasonal processes. Unnecessary artificial light causes serious malfunctions in these biological natures. Light pollution causes many organisms to die, and humans also can suffer from health issues [6].

Read more about the effects of light pollution on biodiversity

The combined criteria of energy efficiency and protection of species were the main criteria considered during the selection of lamps. Also, unique fluorescent stones were placed above the tunnel's northern entrance.

The lamps installed at the "Elbewanderweg" are Siteco mast lights "5XA5412F1A18". They average a lifespan of around 100,000 hours and have a maximum system performance of 20 W with about 86 lm/W. With a colour temperature of 3,000 Kelvin, they are within the range of insect-friendly lighting and are therefore suitable in terms of energy efficiency and the protection of species. Furthermore, they are especially well suited to match said criteria because of their ability to spread the light asymmetrical and thereby leave the potential habitats of animals in darkness [7].

Figure 12. SITECO mast light.

Other lamps installed at the "Elbschlosstunnel" are Survivor 509 Plus. They produce the same colour temperature of 3000 Kelvin with max power consumption 39 W. They produce symmetrical broad-beam light, ideal for the dark tunnel area. Since no bats live directly in the tunnel, no special consideration had to be made.

Read more about preserving darkness in the city

Additionally, input from the theoretical parts of project LUCIA, including the State-of-the-art report about lighting technology, factsheets about technical, economic, social, and GPP aspects, were considered.

The area under investigation for the Pilot Site is divided into functional and design spatial situations. These spatial situations are assigned (design) categories for which technical parameters are defined. Those specific lighting principles developed can be used as general recommendations for actions for similar other areas and sites within the city. They keep all these categories in mind and face the prevailing attitude that Hamburg Verkehrsanlagen (HHVA) provides a choice of luminaires towards respecting green public procurement guidelines and energy efficiency and caring for maintenance after finishing the project in the long run.

The municipality of Hamburg-Altona followed GPP guidelines during the tendering process but also during co-creation activities. An example of the sustainable approach implemented in Hamburg Altona is that only the luminaires are replaced whenever possible during street lighting renovation. The lighting poles are used for as long as possible. The average age of a lamp post in Hamburg Altona is 28 years.

Read more about EU GPP guidelines on road lighting

GPP guidelines were considered during construction works. The district of Altona was responsible for providing general construction works (e.g., digging of cable trenches), and Hamburg Verkehrsanlagen (HHVA) focused on delivering the luminaires. This process follows national tender and procurement rules under the concept of the six-eye principle within the administration that guarantees a strict and fair procedure, including deadlines and specific requirements, for companies who apply for the mandate.

The installation of luminaires was done by HHVA, a city-owned company responsible for over 120,000 luminaires installed in Hamburg. As HHVA has internal procedures for managing required tendering, a little effort was needed from the Municipality. HHVA carries overall responsibility for all tendering aspects, long and short term, regarding luminaires and relevant procedures, including the enforcement of GPP guidelines. The Municipality and HHVA both had to follow GPP guidelines in terms of lifecycle, recyclability of materials, and their origin, similar to many other countries that have included the first generation of EU GPP criteria for road lighting into their internal procedures [8]. The tendering process started in late autumn 2019 and finished in late winter 2020.

Figure 13. Construction and decoration work at the Hamburg pilot site (all photos by Bezirksamt Altona).

2.1.4 Construction

The relevant construction works for pilot site realization and the installation of 29 luminaires were carried out during spring 2020 and completed by the end of September 2020. The construction works, including new decoration for Schröder's Elbschlosstunnel, started in July 2020 and ended in August 2020. The entire constructions process was carried out under COVID-19 restrictions. Altogether, the construction works took longer than expected since the number of workers simultaneously allowed to work on-site was limited. A positive aspect was that the construction works at the tunnel were carried out during warm summer months, which meant that the paint did dry very well. The cleaning of the tunnel from graffiti was done by a professional cleaning company specializing in removing graffiti.

2.2 Pilot site evaluation

To assess the success of the constructed pilot site and gain insight into Municipality procedures, more relevant aspects for the Hamburg pilot site were determined. The identified parts were used to evaluate the situation at the pilot site before and after the completion of the pilot project (see Table 5), providing a base for qualitative and quantitative assessment of its success.

TABLE 5. EVALUATION OF MORE RELEVANT ASPECTS OF THE HAMBURG PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Protection of species	A survey was conducted to investigate the nocturnal insects in the pilot site area. As a result, 50 species (200 individuals) of large butterflies and 26 species (68 individuals) of beetles were recorded. None of the species found was subject to strict legal protection per the Habitats Directive or the Federal Species Protection Ordinance. However, some species of butterflies and beetles were endangered in the Red Lists of the federal states and partly in Germany and were to be considered for general conservation reasons. The population in the old hardwood on Elbschloßstraße, north of Elbchaussee, turned out to be particularly significant, as it contained several beetle species of supraregional importance.	By the time of publishing, no evaluation on the protection of species was carried out, as no significant changes were expected within such a short time.
Energy efficiency	Annual energy consumption of 1,573 kWh, with an average of 197 kWh per luminaire.	Annual energy consumption of 2,033 kWh, with an average of 70 kWh per luminaire.
Monitoring and control	No monitoring and manual switching of lights. Majority of the pilot site without illumination; hence no monitoring and control.	No monitoring and manual switching of lights.
Co-creation	No involvement of the residents in the planning process.	Several co-creation activities were carried out during the pilot site's realization (see Section 2.1.2).

Based on evaluation results, it can be stated that the Municipality of Hamburg Altona met its objective regarding co-creation. In terms of energy efficiency, a significant decrease in energy consumption per luminaire was achieved, although the total energy consumption for the pilot site increased by nearly 30%. Municipalities need to realize that although modern LED lighting promises high energy efficiency, they still consume energy. Energy efficiency in public urban lighting needs to be addressed during the city planning phase to identify which city areas need to be illuminated and the required values of the essential measurable lighting parameters [9]. The Municipality of Hamburg Altona ordered a survey to investigate nocturnal species at the pilot site. Although such a survey was not carried out for the completed pilot site at the time of the publication of this document, it provides a good base of references for future studies and surveys. The Municipality did not fulfil its objectives regarding lighting monitoring and control systems.

In September 2020, a small survey was conducted, focusing on the redesigned Elbschlosstunnel. Thirty-five participants passing through the Elbschlosstunnel were interviewed. Based on responses, no significant increase in the tunnel's usage could be reported. The responses suggested that people felt safe while crossing the tunnel, and it was noticed that the perception of safety while passing the tunnel has not changed with the renovation. Although the sense of security has not changed significantly, public feedback was still positive, which can be attributed to the aesthetic look of the new tunnel, as well as the maintenance and improvements to the pilot site overall

Read more about lighting verification measurements

2.3 Summary

The pilot site of Hamburg Altona is about 1.5 kilometres in length and includes a narrow pedestrian and cyclist tunnel under the street "Elbchaussee" at the corner of the road "Elbschloßstraße."
The redesigned Elbewanderweg features 29 new lamps along the trail, as well as six new lights placed inside the "Schröders Elbschlosstunnel." Numerous co-creation events were carried out in different formats by the Municipality to ensure the residents were involved in the planning process of public lighting at the pilot site. The pilot site construction works were carried out during Spring and Summer 2020 and completed at the end of September 2020. The COVID-19 pandemic was challenging but also fostered innovative formats and novel solutions.

Read more about creating a lighting hierarchy

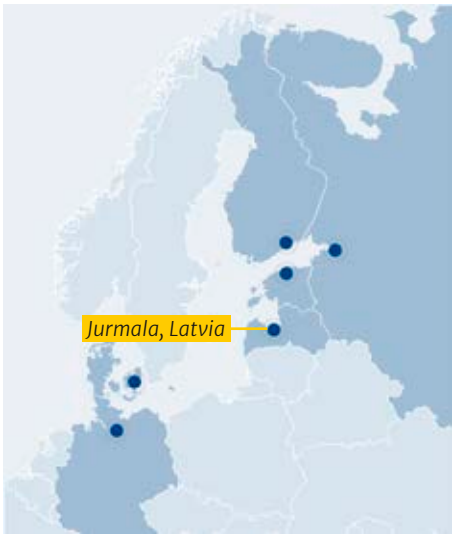
Whether the lighting is considered innovative and sustainable depends mainly on how well it meets the needs of humans and what effect it has on nature. The somewhat contradicting requirements of humans and nature require a high degree of flexibility towards planning, especially in suburban areas. Lighting on cycle paths needs specific light accents and design requirements to avoid vandalism [10]. Environmental conditions are essential to reduce light pollution. A Municipality level lighting plan or lighting hierarchy [11] is required to manage complex tasks during the planning of public lighting.

Read more about protecting public property from damage

Figure 14. LUCIA project pilot site at the "Elbewanderweg" in Hamburg (all photos by Bezirksamt Altona).

3 The role of local businesses and active citizens in transforming public areas (Jurmala, Latvia)

Jurmala is a city in Latvia situated about 25 kilometres west of Riga. It is a resort town stretching 32 km and sandwiched between the Gulf of Riga and the Lielupe River, with a 25 km stretch of white-sand beach and a population of 57,813 (01.01.2021.)[8], making it the fifth-largest city in Latvia.



Jomas Street is a 1.9 km long pedestrian street, meeting point, walking, and recreation area for residents and guests. It welcomes around 3 million people per year, offering a multitude of cafes, restaurants, and other services. Jomas Street has been selected as a pilot site because of its significance for developing Jurmala's image and attractiveness for residents and tourists. [9]

Figure 15. Jomas street, City of Jurmala, Latvia[10].

8 https://www.pmlp.gov.lv/
9 https://en.wikipedia.org/wiki/J%C5%ABrmala
10 https://www.visitjurmala.lv//images/catalog/120b950db3e8c62cd97c31a3639ba7b6/000/000/033/s1_3390.jpg

The street lighting of Jomas street in Jurmala features three spherical luminaires positioned on a single lighting pole. The design is liked by residents and visitors alike, as it is commonly depicted on Jurmala cityscapes, making it an aesthetic landmark feature of the city. The streetlighting relies on Sodium based luminaires and an outdated control system that only enables switching the luminaires either on or off.

Figure 16. Streetlighting at Jomas Street, Jurmala, featuring the iconic three spherical luminaires (photo by Jurmala City Administration).

3.1 Jurmala pilot site of project LUCIA

During project LUCIA, the renovation of illumination of a 1 km strip of Jomas street was carried out. The activities included design, construction, and supervision of replacing approximately 115 lighting poles and 336 luminaires, together with the installation of motion sensors, dimming, and remote-control equipment.

3.1.1 Planning

In the first stages of the pilot project, the municipality also aimed to improve its approach to planning procedures. Although the direct purpose of streetlighting might be straightforward, the specification of a higher-level aim can be challenging. The municipality started the process by asking themselves what they wanted to achieve with this pilot and the purpose of lighting in public spaces. As a result of several internal discussions, communication with residents and local businesses, and workshops with project partners, Jurmala identified four more relevant aspects they want to focus on. The specified aspects were energy efficiency, monitoring, control, multi-functionality, and co-creation (see Table 6). Once the aim of the pilot site was clarified, it was used to guide the planning and budgeting process.

TABLE 6. MORE RELEVANT ASPECTS FOR THE JURMALA PILOT SITE.

CRITERIA	DESCRIPTION
Energy efficiency	The optimization and reduction of energy consumption.
Monitoring and control	The addition or improvement of monitoring and control systems or functions.
Multi-functionality	Emphasis on technology, which enables the creation of novel services, revenue streams and innovative technologies.
Co-creation	The increase of citizen engagement into the planning and design of public areas.

Investments into lighting infrastructure were planned according to Municipality planning documents. It was ensured that the scheduled works aligned with other infrastructure-related construction (e.g., renovation of parks, water, heating systems, etc.). Inhabitants and entrepreneurs were asked for suggestions about the desired functionality of intelligent lighting to ensure lighting sustainability. Valuable input regarding investment strategies for smart urban lighting was received from the LUCIA project [12]. More common replies included that the illumination brightness should follow the actual pedestrian flow and the security should be improved. Ideas were gathered through meetings and questionnaires from residents, local businesses, city planners, and lighting suppliers. The acquired information and suggestions were considered procurement document composition for the technical design of the lighting solution to be installed on Jomas street.

Read more about how to finance smart urban lighting investments

3.1.2 Co-creation

Altogether co-creation activities took up 15% of all the time spent on project-related tasks. The feedback from these activities showed that the results were satisfying. But the number of co-creation activities could be improved. For example, the number of students involved was lower than initially planned.

Activities that allowed personal contact and exchange were far more productive than digital activities. Face-to-face conversations yielded more suggestions than screen-to-screen dialogues. It is also essential to carefully select the target groups, as it is sometimes better to work with a selected group of people instead of the general audience. The form of communication must be chosen wisely to address various target groups, where different communication channels are required for specific target groups.

3.1.3 Design

The requirements for technical design specified the need for dimming, remote control, and monitoring of the lighting system. The designed system needs to integrate motion sensors to enable adaptive control of streetlights based on actual pedestrian flow and provide the possibility to integrate cameras into the system to increase public safety.

Municipality practices, complemented by National GPP guidelines (regulations of Minister Cabinet No.353 (20.06.2017.) "Requirements for green public procurement and procedures for their application") were taken into account when developing procurement specifications. The materials produced during the theoretical parts of project LUCIA,

Read more about what to consider in designing a lighting control system

e.g., the State-of-the-art report about lighting technology [13] and different factsheets about technical, economic, social, and GPP aspects ([14], [15], [16], [17]) provided valuable insight during the design process.

A notable aspect regarding decorative lighting is that GPP guidelines do not explicitly cover it. While streetlights and traffic signals are mandatory EU GPP guidelines, these rules do not apply to decorative lighting. Decorative lighting is not produced based on the same principles as street lighting and traffic signals, which results in decorative lighting having lower energy efficiency than conventional street lighting.

The municipality of Jurmala faced several challenges during the project's design phase. At the beginning of the COVID-19 pandemic in spring 2020, the architect company awarded the contract for technical design provided their initial calculations for the realization of the project, which exceeded the planned budget roughly threefold.

The original plan was to replace luminaires and lighting poles for the entire pilot site. Still, it became evident that such an approach would not be realistic with the corrected budget. Another issue was encountered with the technical design. Although the plan was sound, the designer insisted on using one specific luminaire of one vendor. Since such specification is not in line with Municipality procurement procedures and GPP criteria, the contracted company was asked to modify the provided technical design documents. The results of building procurement showed that the actual costs of replacing lighting poles and luminaires are not as high as planned in the technical project. The municipality of Jurmala was able to secure additional funding for replacing luminaires and lighting poles.

Read more about the state-of-the-art of lighting technology

Read more about how to get started with GPPs

Test installations of luminaires were installed in Jurmala (see Figure 17) to verify the design and technology, which allowed to gather feedback from residents and local entrepreneurs to ensure the support of the public for the solution used at the pilot site.

Figure 17. Before finalizing the technical design, different luminaires were installed and tested for initial verification (photos by Jurmala City Administration).

3.1.4 Construction

As a result of procurement ID No JPD 2021/28 for construction works to renew resource-saving and energy-efficient lighting in Jomas Street, Jūrmala, an agreement was concluded with the company "EL.SERVISS" in July 2021. The constructions works were planned for nine weeks and were finished by the end of September 2021.

The strip of Jomas Street where the lighting was reconstructed spanned from Lienes Street to Turaidas Street and opposite the Majori parking lot in the section reaching from Jomas Street to Lienes Street. During the renovation, 115 existing lighting poles were replaced with new ones, and the existing luminaires were replaced with energy-efficient LED-luminaires. The round design luminaires typical of Jomas Street were preserved during the lighting reconstruction.

Lighting reconstruction works were carried out gradually. First works were performed in the areas where the position of the lighting poles changed. Motion detectors were installed on nine poles opposite the Majori parking lot (Omnibusa Street). The respective construction and installation works were carried out in a way that interfered with the commercial activities of local entrepreneurs as little as possible.

Figure 18. Renovated lighting at the Jurmala pilot site (photo by Jurmala City Administration).

3.2 Pilot site evaluation

To assess the success of the constructed pilot site and gain insight into Municipality procedures, more relevant aspects for the Jurmala pilot site were determined. The pilot site was evaluated, using the identified factors, before and after its completion (see Table 7), hence providing a base for qualitative and quantitative assessment of its success.

TABLE 7. EVALUATION OF MORE RELEVANT ASPECTS OF THE JURMALA PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Energy efficiency	Sodium-based luminaires with an annual energy consumption of 109,192 kWh with an average of 324 kWh per luminaire.	Luminaires based on LED technology with an annual energy consumption of 66,000 kWh with an average of 196 kWh per luminaire
Monitoring and control	No monitoring and manual switching of lights.	Remote monitoring and control using the DALI bus.
Multi-functionality	No additional functionality is included.	Street lighting adapts to actual pedestrian flow in some areas of the pilot site.
Co-creation	Inhabitants and local businesses are not involved in the planning and design of public lighting.	Citizens and local businesses are informed in advance and actively approached and engaged in lighting planning.

As expected, the lighting system's energy efficiency was reduced while maintaining relevant luminous efficacy [18]. The change of municipality procedures occurred as they recognized the benefits of involving residents and local businesses in discussing the lighting of public areas.

3.3 Summary

During the pilot project, the lighting system on a 1 km strip of Jomas street – the busiest street of Jurmala, has been improved. The replaced luminaires increase the lighting system's energy efficiency by 40%. Dimming functionality and DALI communication enable improved monitoring and control.

The energy efficiency is further increased by utilizing motion sensors that control lighting conditions based on actual pedestrian activity. These improvements were planned and designed in close coopera-tion with local businesses and inhabitants to meet their real needs. As a result, the visitors of Jurmala can enjoy the aesthetics the city has to offer. At the same time, the residents and local businesses can say they have shaped the public spaces in their town to increase overall wellbeing and contribute to a sustainable future.

Read more about energy efficiency and luminous efficacy of LEDification

Figure 19. LUCIA project pilot site at Jomas Iela, Jurmala (all photos by Jurmala City Administration).

4 Public lighting infrastructure for connecting people (Porvoo, Finland)

Porvoo is a city and a municipality in the Uusimaa region, Finland, situated on the southern coast about 50 kilometres east of Helsinki. It is one of the six medieval towns in Finland, first mentioned as a city in texts from the 14th century. Porvoo is internationally considered one of the most beautiful towns in Finland, as it enjoys the reputation of one of Finland's most popular summer towns and boasts a unique cosy atmosphere during the long and dark winter.[11]

The Länsiranta area on the western riverbank of the river Porvoonjoki is currently developing in Porvoo. The site combines public services, residential areas, a location to hold bigger events, different parks, and a recreational area. Due to its attractive location, the Municipal Engineering Department of the City of Porvoo selected the pedestrian route in Länsiranta as the pilot site in project LUCIA.

Figure 20. City of Porvoo, Finland (photo by Niklas Montonen[12]*).*

11 https://en.wikipedia.org/wiki/Porvoo
12 Avaliable at: https://www.flickr.com/photos/aixcracker/49211974486/in/pool-porvoo/

Figure 21. The "Länsiranta" area of the Porvoo pilot site.

4.1 Porvoo pilot site of project LUCIA

The city of Porvoo is building a new pedestrian route along the Porvoo river, together with public lighting. The construction is carried out at two locations: on the northern and southern sides of Aleksanterinkatu Bridge.

The city of Porvoo aims at bringing new intelligent and energy-efficient lighting into the area. The illuminated pedestrian route does provide not only comfort but also a sense of security. Since there are residential areas and public services in Länsiranta, the illuminated pedestrian route serves both residents and customers. The illuminated pedestrian route also attracts tourists and boaters passing by. Additionally, a direct link between two parts of the city encourages residents to use a bicycle or walk instead of using a car to get around.

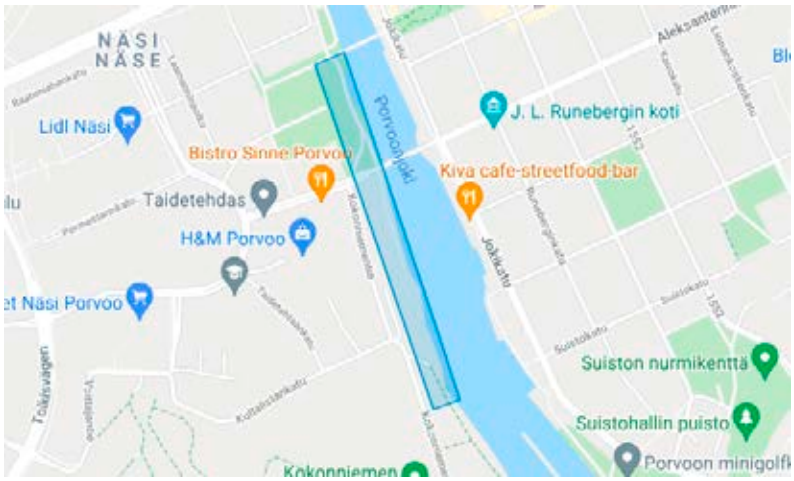


Figure 22. New pedestrian route between central Porvoo and the Länsiranta area.[13]

13 https://www.google.com/maps

Along the new pedestrian route between central Porvoo and the Länsiranta area, a new lighting system that includes atmospheric lighting and other features are installed according to a concept to be developed by a designer. The city is building this new pedestrian walkway and lighting system along the river Porvoonjoki.

Figure 23. Porvoo "Länsiranta" area before project LUCIA (photo by Topi Haapanen).

4.1.1 Planning

The municipality identified four more relevant aspects they wanted to focus on in the planning phase. The specified aspects were energy efficiency, improvement of lighting parameters, use of multi-functional technology, and improvement of overall public opinion (see Table 8). Once the aim of the pilot site was clarified, it was used to guide the planning and budgeting process.

TABLE 8. MORE RELEVANT ASPECTS FOR THE PORVOO PILOT SITE.

CRITERIA	DESCRIPTION
Energy efficiency	The optimization and reduction of energy consumption.
Lighting	The improvement of specific lighting parameters in the pilot site.
Multi-functionality	Emphasis on technology, which enables the creation of novel services, revenue streams and innovative technologies.
Public opinion	The increase of positive public opinion.

Although GPP guidelines were not explicitly included in the tenders, the GPP requirements and a sustainable mindset were used throughout the process, such as materials, appliances, and functions of light were designed using the environmental aspect:

- Foreseeing the use of LED luminaires.
- Considering the minimization of light pollution during the selection of lamp design.
- Exploring sustainable and multifunctional equipment (street lighting with integrated photovoltaic panels).
- The use of energy-efficient and innovative technology to adjust lighting according to the environment.

4.1.2 Co-creation

Co-creation activities were carried out in Porvoo at two significant events to engage residents in the planning procedures.

At the Porvoon Valot light festival, the residents of Porvoo were introduced to the LUCIA project and could share their opinions and wishes for the planning area. On the topic of lighting, the participants could talk concretely about their perceptions and preferences, e.g., which shade of lighting is most preferably warm or cold? A survey was used to collect the opinions. The event was open to all interested parties, and no registration was required.

The second event, the vision workshop webinar, focused on the views and needs of different groups and stakeholders. The workshop put together themes for the vision: well-being and experimentalism, energy and cost savings, maintenance, safety, light pollution, and ecology. The workshop addressed different groups, e.g., the elderly, young people, the visually impaired, entrepreneurs. The vision workshop was an excellent opportunity to get opinions from other groups and co-create the vision to plan the lighting in the pilot area.

A third event, an "experiential walk," was also planned but had to be laid off due to COVID-19 related restrictions.

4.1.3 Design

Ramboll Finland Ltd carried out the lightning design for the Länsiranta's smart lighted pedestrian path. The lighting design consisted of technical and visual design and planning the co-creational activities.

In the technical design, close co-operation was established between Ramboll Finland Ltd., the City of Porvoo, and Porvoo Sähköverkko Ltd. Still, the results of the co-creational activities were also considered in the technical design. The goal was to have a functionally versatile solution that enables value-added servicing through novel technology. In addition, the concept design creates a framework for the development of the Länsiranta for different needs of events and arts.

The intelligent lighting solutions in the parks Aleksinpuisto and Taidetehtaan rantapuisto form a modular smart light pole and additional services, such as speakers, sound beacons, gobo-fairway signs, photovoltaic panels, and wireless phone charger. The luminaire poles are LED luminaires from the SeluxLif collection, and the control of intelligent lighting is implemented using the Capellon – control system.

The requirements for technical design specified the need for dimming, remote control, and monitoring of the lighting system. The designed

Read more about key strategies to link economic development and smart urban lighting

system was required to integrate motion sensors to enable adaptive control of streetlights based on actual pedestrian flow and provide the possibility to integrate cameras into the system to increase public safety.

4.1.4 Construction

The construction of the LUCIA pilot site involved many separate construction works that were coordinated with each other. The pathway was designed to be built on undeveloped soil with no pre-existing infrastructure. Construction has thus begun with removing old contaminated soils and extensive ground reinforcements on both sides of the Aleksanterinkatu bridge. In the park Taidetehtaan rantapuisto, deep stabilization was implemented earlier. In park Aleksinpuisto, pillar and lamella stabilizations began in November 2020.

In the park Taidetehtaan puisto, the LUCIA pathway is bordered by a rocky riverside slope, referred to as "kiviheitoke ranta" (rock-throwing beach), which implementation started early 2021. For the park Taidetehtaan rantapuisto, the waterfront also includes new boat docks installed in late autumn 2021.

In the park Aleksinpuisto, the construction includes, in addition to the pre-constructions, a 109 m long reinforced concrete structured waterfront wall and a recreation park surrounding the LUCIA pathway. The waterfront wall structure was completed in August 2021, and the surrounding park in 2022.

Jeti-Sähkö Ltd carried out lighting installations. During the construction, emphasis was placed on coordinating and scheduling different projects, separate construction works, and actors. The construction process was delayed due to unsuitable weather conditions, namely high levels of water in the river and groundwater

Figure 24. Construction works at the LUCIA pilot in Porvoo (all photos by Topi Haapanen).

4.2 Pilot site evaluation

The aspects that were determined to be more relevant for the Porvoo pilot site were used to assess the success of the constructed pilot site. Based on the identified more pertinent aspects of the Porvoo pilot site, evaluation activities were carried out to evaluate the situation at the pilot site before and after the completion of the pilot project (see Table 9).

TABLE 9. EVALUATION OF MORE RELEVANT ASPECTS OF THE PORVOO PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Energy efficiency	Not applicable	State-of-the-art LED luminaires with a Capellon control system provide high energy efficiency.
Lighting	Not applicable	Lighted pathway with minimized light pollution.
Multi-functionality	Not applicable	Light poles not just provide light but also voice guidance for the visually impaired, sound art, plugs for different events, and seasonal lights
Public opinion	Residents mainly perceived the area as safe, while some respondents experienced insecurity.	The Municipality of Provoo monitors public opinion to evaluate relevant changes.

The pre-evaluation was carried out before the construction works at the pilot site, during February and March 2021. The subject of the pre-evaluation was the comfort and safety of the Länsiranta area. The pre-evaluation was conducted in a questionnaire and reached 40 park area residents.

Based on the survey responses, the area was already widely used during the survey: approximately 50% of respondents visited the site several times a week, while roughly 38% even visited it once or several times during a day.

The new park area is centrally located in the centre of Porvoo and will, upon completion, complement the area's cityscape. There are also many apartments near the park area. Approximately 98% of the respondents indicated that they take walks around the site, and roughly 40% use it for cycling. The area is used primarily for recreation and as a bypass, sports venue, or path for work and school commute.

Approximately 77% of the respondents feel that different seasons affect their movements in the area, which explains why there is less movement in winter than during summer. The main reasons indicated by the respondents were lack of light and slippery, icy surfaces during winter.

Residents were asked to rate the comfort of the area on a scale of 1 ("I do not feel comfortable at all") to 5 ("very comfortable"). The mean score of the responses was around 2,7, and the respective comments indicated that the lack of decent lighting and walkways in the area were mainly accountable for a negative score. Residents were also asked to rate the safety of the site on a scale of 1 ("not safe") to 5 ("very safe"). The mean score of the responses was approximately 3,6. Based on the answers, it could be concluded that residents mainly perceived the area as safe. Still, some respondents shared that they experience insecurity due to lack of lighting, as dark spots are perceived as uncomfortable and do not encourage movement around the area.

4.3 Summary

Read more about economic benefits of multi-functional smart urban lighting

The illuminated LUCIA pathway was completed by September 2021, while the surrounding area took longer. The interest of cafe service providers and entrepreneurs has arisen, and the two cafe-restaurant plots in the park area are now reserved. No one was interested in them in the past, but this cannot be credited to lighting alone. Nevertheless, the positive change is undoubtedly initiated by the overall ambience of the area, which has been holistically created using multi-functional lighting to increase the interest of residents and entrepreneurs [19].

One of the essential themes of the entire LUCIA project and the lighting design process at the LUCIA site in Porvoo was co-creational activities and their implementation. Two different events were organized during the LUCIA project. Residents participated diligently and provided essential comments and opinions for the lighting plan. The sound beacon was one of the better ideas that emerged from the vision workshop. The sound beacon guides the visually impaired people to navigate the area safely. The beacon identifies the target user through the phone's application, and the beacon starts to play a guiding sound or a bird-like song. The sound beacon guides the entire LUCIA pathway.

In the future, the Länsiranta area will serve all residents, guests, and tourists in a magnificent recreation area offering a wide range of services and technology. After completing the LUCIA pathway on foot or by bike, it is rewarding to enter the Länsiranta area.

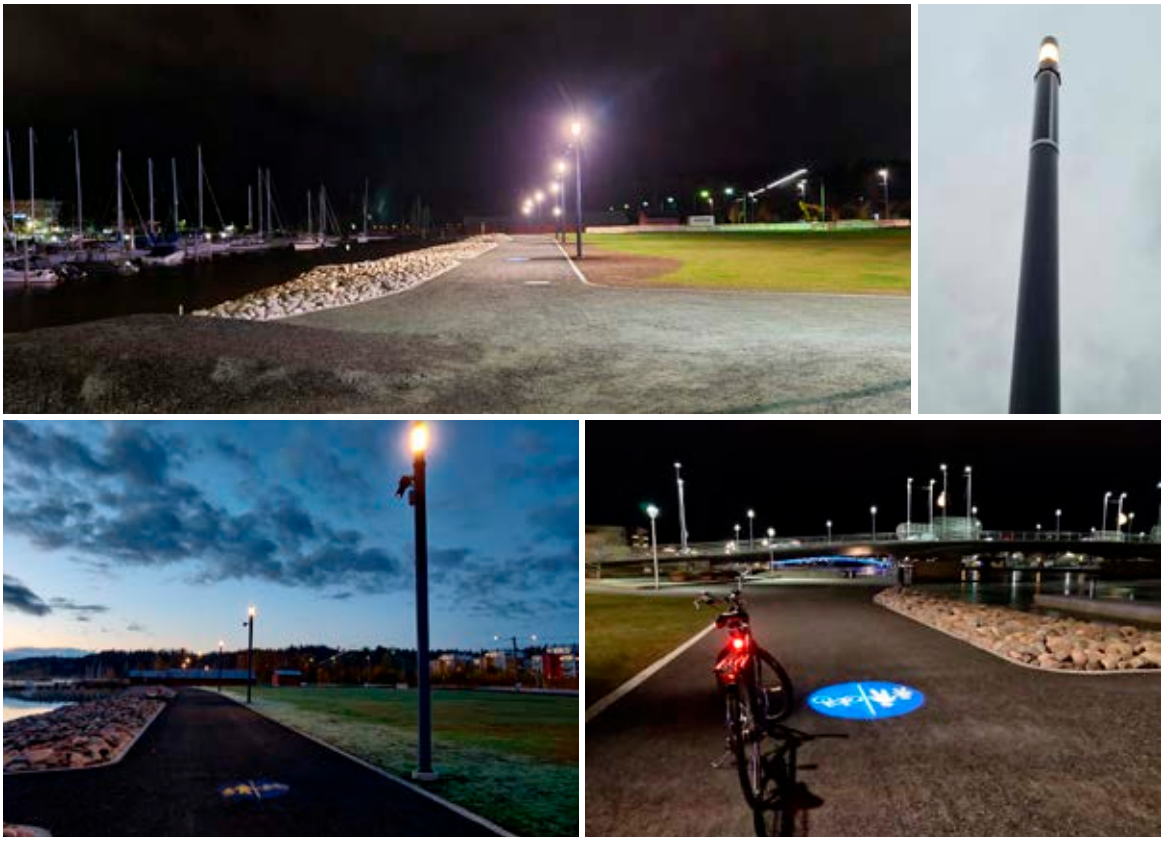


Figure 25. LUCIA project pilot site at the Länsiranta area of Porvoo (photos on top by Tarmo Korõko, photos at the bottom by Topi Haapanen).

5 Innovation and traditions to complement each other (St. Petersburg, Russia)

Saint Petersburg is the second-largest city in Russia. It is situated on the Neva River, at the head of the Gulf of Finland on the Baltic Sea, with roughly 5.4 million residents. Saint Petersburg is the fourth-most populous city in Europe, the most populous city on the Baltic Sea, and the world's northernmost town with over 1 million residents. As Russia's Imperial capital in the past and cultural capital at present, it is governed as a federal city.[14]

The Peter the Great St. Petersburg Polytechnic University (SPbPU) campus is located in the north part of the city. Its total area exceeds 250,000 sq. m. and contains historical and modern educational, social, research, residential buildings, and green and sports areas.

Figure 26. City of St. Petersburg, Russia (photo by A.Savin, WikiCommons[15]*).*

14 https://en.wikipedia.org/wiki/Saint_Petersburg
15 https://commons.wikimedia.org/wiki/File:Spb_Views_from_Isaac_Cathedral_May2012_09.jpg

Figure 27. Peter the Great St. Petersburg Polytechnic University campus (Image provided by SPbPU).

The land and real estate at the SPbPU campus belong to the state. SPbPU has the right of unlimited use and is obliged to maintain and use them for educational purposes. SPbPU Department of Chief Engineer provides necessary works to maintain and develop this territory and buildings, including outdoor functional and artistic lighting.

Figure 28. Artistic lighting at the SPbPU campus (images provided by SPbPU).

5.1 St. Petersburg pilot site of project LUCIA

Outdoor lighting on the campus was installed at the end of the last century and needs modernization. Recent developments on SPbPU campus territory foresaw the installation of 22 multifunctional luminaires at the LUCIA pilot site. The intelligent lighting was combined with artistic illumination of the main building, water tower, and other historic buildings to provide energy-saving solutions and improve the comfort and perceived safety on the campus.

Figure 29. Historical lamp posts at the SPbPU campus (all photos by Yury Nurulin).

Several buildings in the SPbPU campus have the status of Federal Cultural Heritage. Based on current legislation, all work to be performed on this territory needs to ensure the preservation of the cultural heritage object. It is required to coordinate all activities with the Committee for State Control, Use, and Protection of Historical and Cultural Monuments of the Government of St. Petersburg (referred to as the Committee). As a prerequisite, an appropriate permit was required from the Committee to start construction works at the pilot site. Relevant permissions were obtained in September 2019, which contained a list of mandatory jobs related to the survey of the territory and the restoration of green spaces, and the restoration of the historical appearance of outdoor lighting.

Figure 30. Historical public lighting at the SPbPU main building (photo by Yury Nurulin).

5.1.1 Planning

The campus territory is considered an integral system with subsystems of technic and technology, organization and economy, cultural heritage, and end-users preferences and behaviour. The project LUCIA is piloting sustainable outdoor lighting at the SPbPU campus. The solutions tested at the pilot site are further extended to the whole territory of the campus. The general goals of developing outdoor lighting at the SPbPU campus are low energy consumption, increased safety while preserving cultural heritage, and protecting flora and fauna.

The planning for the renewal of the lighting system at the SPbPU campus began before the official launch of LUCIA. It focused on analyzing the current installation (age, type, lighting profile, luminaires, lampposts construction and appearance, cable lines coordinates) and communicating with the Committee to get necessary permits for the work. As the Russian Federation has not adopted EU GPP guidelines, including them in the planning process was unnecessary. However, as GPP guidelines provide valuable input for improvement, the LUCIA team of SPbPU made good use of the documents compiled during project LUCIA, e.g., to get directions on implementing GPP guidelines [17].

Read more about getting started with EU GPP guidelines

After the official start of LUCIA, several working meetings were held for planning the renovation of the lighting system on the SPbPU campus, including the LUCIA pilot site. Specialists from SPbPU Tender's Department and Juridical Service were involved in the planning and realization of purchases of goods and services for renewal of the lighting system as members of the SPbPU LUCIA project team. A cooperation agreement with the municipal outdoor lighting company of St. Petersburg, LENSVET, was signed, and their experts supported the planning with corresponding knowledge. Based on discussions between SPbPU project team members and LENSVET experts, determine the aspects to focus on at the pilot site. The specified factors were lighting, energy efficiency, monitoring and control, and reliability (see Table 10). Once the aim of the pilot site was clarified, it was used to guide the planning and budgeting process.

TABLE 10. MORE RELEVANT ASPECTS FOR THE ST. PETERSBURG PILOT SITE.

CRITERIA	DESCRIPTION
Lighting	The improvement of specific lighting parameters.
Energy efficiency	The optimization and reduction of energy consumption.
Monitoring and control	The addition or improvement of monitoring and control systems or functions.
Reliability	The emphasis on technologies that are more reliable and increase reliability of the lighting system.

The last planning step was focused on preparing tender documents according to internal SPbPU regulations. The key figures in this process are the experts of the Tender Department. They mainly control the implementation of the formal requirements of the legislation on the organization of tender procedures. The standard selection criterion is price, where the lowest offer determines the winner, much to the detriment of quality and advanced technical parameters. A well-known approach that can partly protect against such situations is detailed documentation for technical terms of reference, indicating the development object's required technical parameters and characteristics. SPbPU experts used the documents produced during the implementation of the LUCIA project, the state of the art report [13], for example, while developing the technical terms of references for the technical design that was also agreed with LENSVET.

5.1.2 Co-creation

Read more about the LUCIA mid-term webinar series

The SPbPU LUCIA team focused its co-creation activities on local students and considered the pilot site's primary users. Therefore, a working group of students who were actively engaged in the issues of intelligent energy-efficient outdoor lighting was formed. The aim was to inform, listen to and engage students and others to get them involved in co-creation activities by injecting outdoor lighting topics into their regular education program (student research and bachelor theses). Information and project materials were provided to report on issues related to LUCIA and the planned activities. Feedback was continuously generated through discussions, surveys, and personal exchanges. The dissemination of the project materials resulted in a new perspective on outdoor lighting that does not solely emphasize illumination during nighttime but also stresses the importance of seeing the stars after dark.

An intensive exchange about light arose during work on two theses. One student focused on intelligent outdoor lighting of the SPbPU campus during her bachelor's thesis. Two other students organized and analyzed an extensive survey among students (participation of 169 students) and helped to create two videos about the LUCIA pilot site. Ten SPbPU students participated in the LUCIA mid-term webinar held on October 14 [20], 2020. The webinars could impart a great deal of new knowledge dealt with further in the project and added to their educational basis.

The engagement of LENSVET was used for expanding the target audience of co-creation measures. In May 2020, LENSVET held an open children's drawing competition dedicated to St. Petersburg at night. Six-year-old Maria participated in this competition with the picture "Polytechnic in the light of lanterns" based on the presentation of the LUCIA pilot site in SPbPU. The author received an official letter of appreciation from LENSVET.

In April 2021, LENSVET held the roundtable discussion "Safety and quality of LED luminaries" in the frame of XII international exhibition and conference "Housing and communal services of Russia." LUCIA activities were presented and discussed at this roundtable event. The feedback received from participating experts provided helpful knowledge for the LUCIA SPbPU project team, while Russian specialists were invited to visit the LUCIA Knowledge Center.

As an outlook to further working phases, the possibility of expanding the target audience of co-creation measures was discussed through cooperation with the Sirius Centre – the Federal Centre for Youth Development (Sochi). Negotiations on specific forms of possible cooperation were held in late December 2020, January, and June 2021.

Co-creation activities in the project were implemented by experts from the project team that has close links with students of two SPbPU Institutes because of their primary duties as teachers.

Figure 31. Picture of LUCIA SPbPU pilot site (photo provided by SPbPU).

That is why the central active students presented these Institutes. Existing student societies of SPbPU ReGreen, Energy Club, Polytech Case School, and Kino Polytech were informed about the LUCIA project and invited to participate in relevant events to increase student participation in LUCIA activities.

Working with students showed that they have fresh and innovative ideas, are flexible, ambitious, and open to cooperation. One difficult question to answer, though, was how the ideas and feedback of students could be incorporated into actual work at the pilot site. Therefore, the motivation among students needs to be increased by demonstrating that the opinions of students, staff, and residents were considered and allowed to influence decisions.

Experience with organized activities showed that digital events could reach a wider audience, but face-to-face events provided more effective feedback. A combination of digital and personal interaction should be considered the optimal solution.

5.1.3 Design

The tender for the technical design of the outdoor lighting system at the SPbPU campus was organized in May 2020, and the contract with the winner was concluded in early June 2020. When coordinating the project with the Committee, several sections were added to the list of necessary works on request of the Committee. Due to this, an additional agreement was concluded with the contractor to extend the work term by three months and slightly increase the work's cost.

Two main challenges were met during the design process. The first one was related to getting approval from the Committee. COVID-19 related restrictions significantly increased the time required to obtain work permits in the protected area and coordinate design solutions. The more significant issues raised were accommodating the increased volume of control system equipment in the limited space inside historical forms and where to place surveillance cameras and other security system elements. The Committee accepts only finalized technical documentation for evaluation, including equipment placement on lighting poles. If the Committee does not approve the proposed appearance, the technical design is rejected and subject to redesign. Several options for lamp post appearances were developed and presented to the Committee to speed up this process. Also, electrical cabinets in historical style were designed to house additional equipment (see Figure 32).

Figure 32. The designed appearance of new lamp posts (images provided by SPbPU).

The second challenge was related to the ability of the contractor to carry out technical design with the necessary quality. Developed technical documentation was presented to SPbPU in March 2021. Still, it was rejected by the experts since its composition did not meet the requirements of the terms of references, and the proposed technical solutions were not sound. As a result, SPbPU unilaterally cancelled the previously concluded contract and, following the current procedures, agreed with a new contractor in May 2021 to develop technical documentation of the outdoor lighting system for the pilot site LUCIA.

5.1.4 Construction

The preparation of tender documents for construction started in May 2021. The tender was announced in June, and the contract was signed in July 2021. This way, some necessary formal steps to prepare for the construction tender were carried out in parallel with the final stages of the technical design, which makes it possible to compensate for the time lost in the design phase.

Lighting calculations performed during the technical design phase indicated that the number of lampposts in the pilot area should be 25 instead of the previously planned 22, and the cost of these lampposts is higher than initially planned as it is based on individual (non-standard) design. Two additional specialists were invited to the project team for continuous progress monitoring of construction work, and regular working meetings were held to resolve possible issues and difficulties promptly.

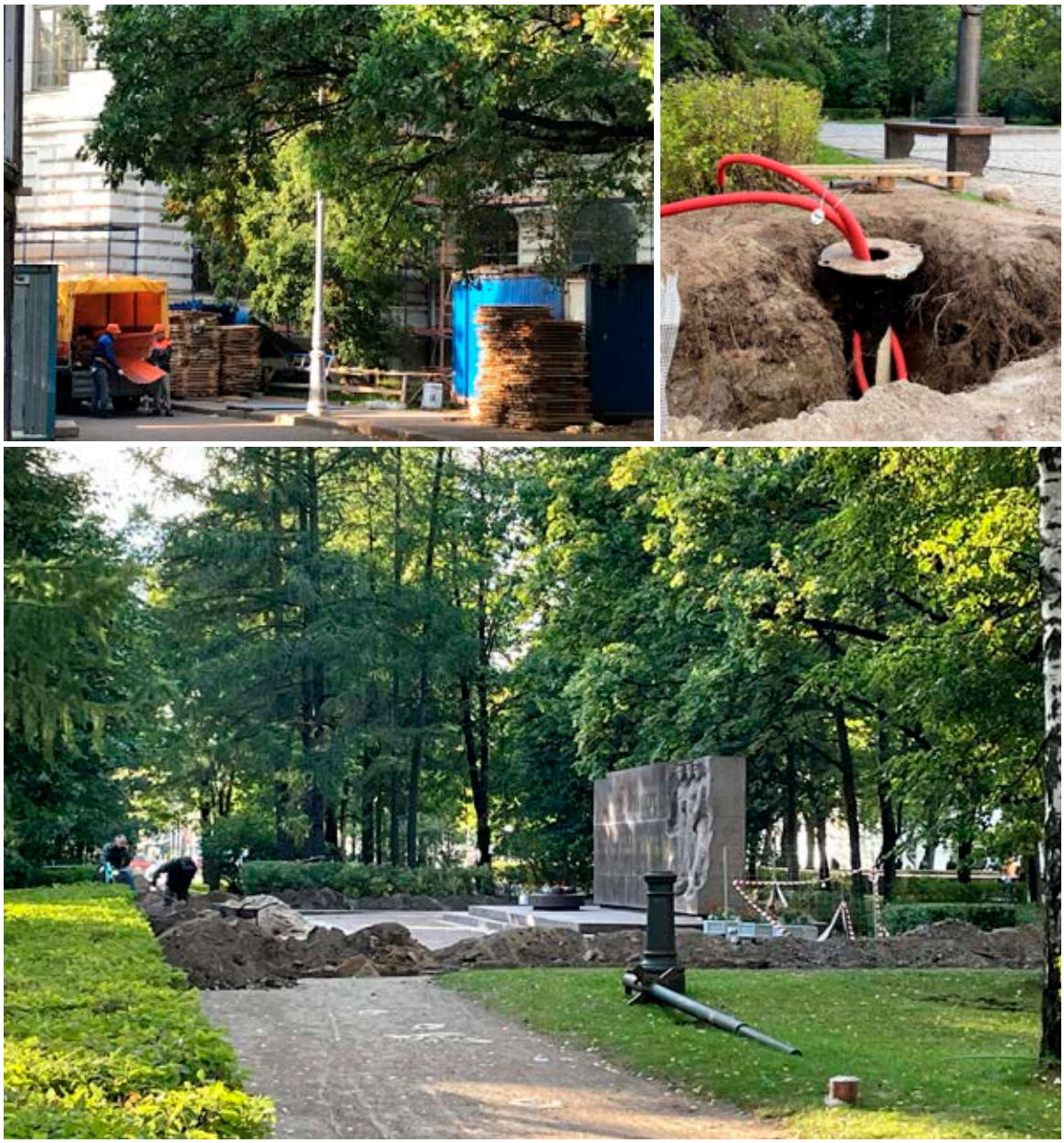


Figure 33. Construction works at the LUCIA pilot site in St. Petersburg (all photos by Yury Nurulin).

5.2 Pilot site evaluation

The aspects that were determined to be more relevant for the St. Petersburg pilot site were used to assess the success of the constructed pilot site. Based on the identified more pertinent aspects of the St. Petersburg pilot site, evaluation activities were carried out to evaluate the situation at the pilot site before and after the completion of the pilot project (see Table 11).

TABLE 11. EVALUATION OF MORE RELEVANT ASPECTS OF THE ST. PETERSBURG PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Lighting	22 gas-discharge sodium lamps "ДНаТ." No specific lighting parameter was measured before the realization of the pilot site.	25 LED lamps "V11-01/1(ДСУ11-60-011)." Lighting-specific requirements were defined in the technical terms of references, and the installed luminaires met the criteria. No specific lighting parameter was measured after the realization of the pilot site.
Energy efficiency	Annual energy consumption of 22,000 kWh, with an average of 1,000 kWh per luminaire.	Expected annual energy consumption of 5,280 kWh, with an average of 211 kWh per luminaire.
Monitoring and control	No automated control system of outdoor lighting. No metering of consumed energy for lighting.	Individual control with dimming and feedback. Automatic metering of consumed energy with remote data transmission
Reliability	Failure rate: Two times a year.	Expected failure rate: once every five years.

The technical evaluation of the created outdoor lighting system was based on verifying the ToR requirements, which was carried out during the acceptance of the work. Qualitative assessment of the lighting system at the SPbPU campus before the LUCIA project was based on students' feedback. Criticisms regarding the presence of dimly lit areas, the appearance of the poles, and the lack of emergency calls and access to the Internet were taken into account when developing the new system.

The ability to quantify the energy efficiency of the old system was limited since it did not have a metering unit for consumed electricity. In this regard, accurate data from the new system and calculated values from the old system are used for comparative analysis, which, naturally, reduces the reliability of this analysis. The results on the reliability of the created system become available only during its operation.

Read more about improving reliability of lighting systems

5.3 Summary

Despite the limitations associated with the COVID-19 pandemic and problems that arose during technical design, the LUCIA pilot site at SPbPU was completed on time and in full.

Figure 34. The LUCIA project St. Petersburg pilot site at SPbPU (photos by Yury Nurulin).

The multifunctional and intelligent lighting system at the LUCIA SPbPU pilot site comprises 25 lighting poles with LED luminaires, a modern control system, video surveillance equipment, and wireless Internet access points. The knowledge and experience that SPbPU experts got during the project disseminate the pilot project results to the entire campus.

6 Unlock creativity while designing public areas (Tallinn, Estonia)

First mentioned in 1154, Tallinn is the capital and the most populous city of Estonia, with around 450,000 inhabitants. Located in the northern part of the country, on the shore of the Gulf of Finland of the Baltic Sea, Tallinn is located 80 kilometres south of Helsinki, Finland, 320 kilometres west of Saint Petersburg, Russia, 300 kilometres north of Riga, Latvia, and 380 kilometres east of Stockholm, Sweden. Tallinn has a rich history as a medieval port city and is a member of the Hanseatic League. Its Old Town, located in the Kesklinn district, is one of the best-preserved medieval cities in Europe and is listed as a UNESCO World Heritage Site.[16]

Figure 35. City of Tallinn, Estonia(photo by Kaupo Kalda[17]*).*

16 https://en.wikipedia.org/wiki/Tallinn
17 Kaupo Kalda, Tallinn City Tourist Office & Convention Bureau, https://www.puhkaeestis.ee/et/ponevad-paigad/tallinn

Canute Garden is one of the parks forming a "green belt" around Tallinn's medieval Old Town. In 1953, the park was designed as a neo-classical park. Canute Garden contrasts the modern urban ambience and is a popular location during the summer for tourists.

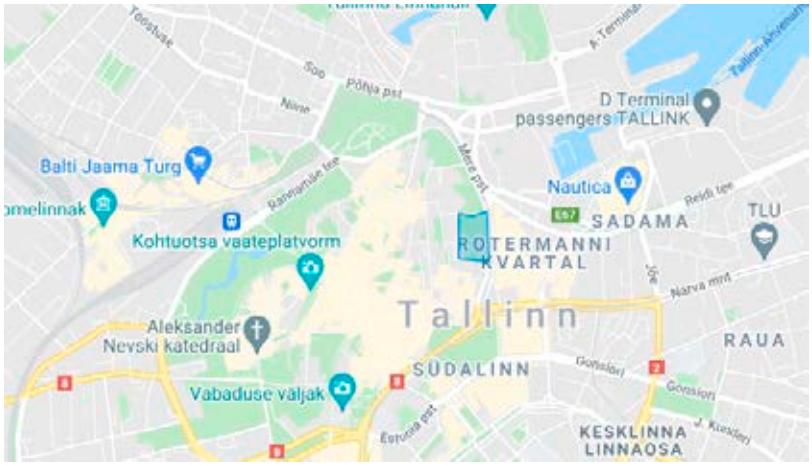


Figure 36. Canute Garden Park, one of the Bastion Zone parks surrounding the historic Old Town of Tallinn. [18]

Figure 37. Lighting in the Canute Garden Park in Tallinn before LUCIA (photo provided by Tallinn City Government).

18 https://www.google.com/maps

6.1 Tallinn pilot site of project LUCIA

The general idea of the City of Tallinn pilot site was about creating a park of seasons: the light changes according to seasons, using different possibilities of modern lighting. There was also social ambition: bringing life to the park during dark times of the day. The Park is a cultural heritage asset, and the lighting was renewed to create harmony with the lights of the nearby Old Town city walls and towers.

Although the park is situated in the middle of Tallinn, there have been problems with hooligan gangs. Results of public questionnaires indicate that the feeling of safety is low in the area. The LUCIA pilot project in Tallinn aims to raise the sense of security, replace old lightings solutions with modern ones, and create an attractive, inviting urban place with a strong identity.

A thematic lighting plan is developed for all Tallinn's Bastion Zone parks. The thematic plan is realized in Canute Garden, one of the Bastion Zone's parks. In Canute Garden, old pole lights are replaced with LED lighting. Furthermore, intelligent decorative lighting shall be installed to illuminate a fountain, a playground, and the main seating area within the park.

Figure 38. Pilot site of Tallinn, "Canute Garden" (photo provided by Tallinn City Government).

6.1.1 Planning

The municipality identified four more relevant aspects they wanted to focus on in the planning phase. The specified aspects were public safety, energy efficiency, fostering creativity, and improvement of overall public opinion (see Table 12). Once the aim of the pilot site was clarified, it was used to guide the planning and budgeting process.

TABLE 12. MORE RELEVANT ASPECTS FOR THE TALLINN PILOT SITE.

CRITERIA	DESCRIPTION
Safety	The increase of citizen safety and sense of security.
Energy efficiency	The optimization and reduction of energy consumption.
Creativity	The purpose of creating something novel and artistic.
Public opinion	The increase of positive public opinion.

EU guidelines for GPPs were considered during the planning and design phases of the construction of the pilot site. An in-depth comparison was made between the EU GPP criteria and the guidelines already implemented in the practices of the Tallinn City administration. The following documents were used throughout the planning and construction process:

- Technical conditions for street luminaires under subsection 14 (5) of the Regulation of the Minister of Economic Affairs and Infrastructure "Conditions for Supporting the Renovation of Street Lighting Infrastructure" (RT I, 09.08.2016, 1),
- EU Green Public Procurement Criteria for Road Lighting and traffic signals,
- TECHNICAL SPECIFICATION NMF01:2018 LED luminaires – requirements; Edition 2.0.
- LUCIA project material about sustainable procurements [21] and lighting systems [22].

Read more about making your procurements mor sustainable

6.1.2 Co-creation

The objective behind the idea gathering effort during the LUCIA project was firstly to collect the opinions and suggestions of city residents concerning the current and prospective park lighting in the Bastion belt, but also to find out what they think about the usability, routes, and feeling of safety in the parks. A public online survey was organized for these purposes, supplemented by interviews conducted with Tallinn's old town residents. As the gardens are situated around the old town, the aim was to gather the opinions of Old Town residents concerning the perception of safety and other lighting issues.

In a guerrilla lighting workshop, the Tallinn project team raised awareness of how lighting can transform places. Citizens had the opportunity to give feedback on lighting ideas and try out different lighting variations on site. Participants could check other lighting techniques and technologies, test the correct power (lumens) of fittings, try out different light colours, and take beautiful pictures for project publicity. As an event of tests and trials, the guerrilla lighting workshop helped check out how other lighting solutions work on site.

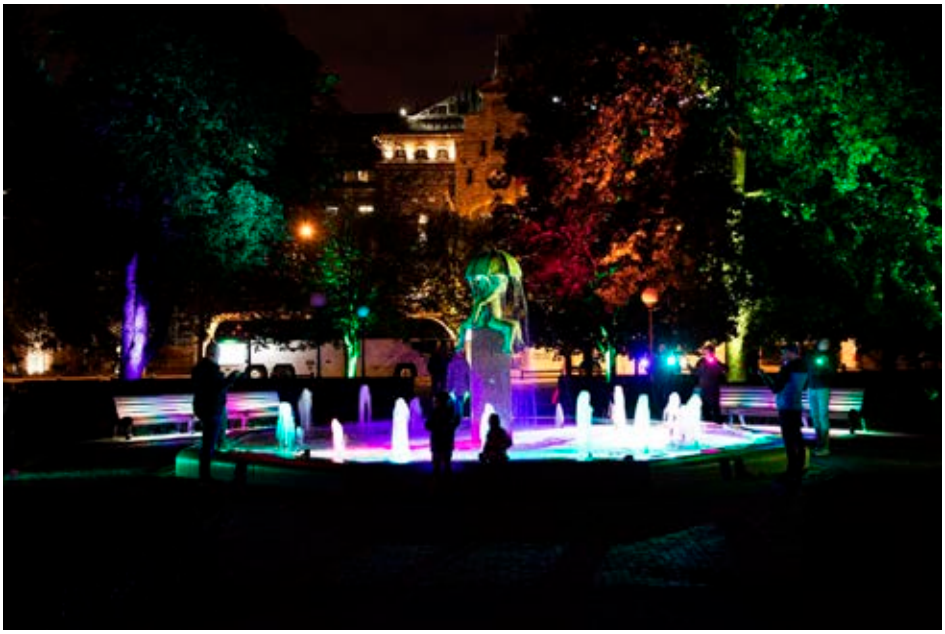


Figure 39. Guerilla lighting workshop in the Canute Garden, LUCIA's pilot site in Tallinn, Estonia (photo by Eva Tallo).

In addition to the participation formats involving citizens, an intensive exchange also took place with city employees. A workshop with city workers brought together city planners, city district specialists, landscape architects, organizers of the city's light festival, and politicians to jointly work on a project to create a safe and pleasant urban environment. The workshop aimed to exchange information, identify key challenges, frame ideas, set budgets, discuss heritage demands, etc. In the seminar, critical elements of good and poor lighting were discussed. In the practical section, schemes and maps of the park were used to define zones and activities. The task of the working groups was to propose a concept describing which objects should be illuminated and in what manner.

External input was acquired through an international idea competition to obtain a professional park lighting concept. All other co-creation activities provided relevant information for this competition. The desired outcome was a schematic lighting design plan for the pilot site at Canute Garden. The results of all the co-creation activities were evaluated against the stated aims.

The results of all these co-creation activities helped lighting designers come up with a satisfying lighting concept and a thematic lighting plan for all the Bastion parks. The co-creation events were successful, and the selected target groups provided excellent and relevant results. One example of the challenges was the complete reversal of the initial ideas and opinions expressed. People do not always know what they want, which also applies to lighting, which needs to be considered when involving the public. They also often make no difference between good and bad lighting, so they must be educated first. It is not easy to make decisions on a broader scale if there are too many different opinions, so the options must be narrowed first before asking people their opinions. An essential fact to remember is that even though some community members are more active than others, one cannot generalize based on their views. Hence it is crucial to engage a broad and varying target group.

6.1.3 Design

To foster creativity, the City of Tallinn decided to use an international idea competition to engage artists around the EU in providing a holistic lighting design for the Bastion Zone Parks. The International idea competition was directed to lighting designers and engineers, and the subject of the competition is the thematic plan for lighting Tallinn's Bastion Zone parks. The thematic planning shall ensure lighting functionality by providing guidance and ensuring the safety of people. At the same time, it shall also value and protect nature and the environment, create a suitable atmosphere, and exhibit urban art.

Read more about key criteria for a green lighting system

The design competition aimed to find the perfect lighting design solution for Tallinn's Bastion Zone parks. The goal was to create safe, pleasing, energy-efficient, and innovative lighting solutions for the gardens, the design of which would last for decades in the respective climate. The thematic planning needs to provide answers to the following questions: what, how, and how much should be illuminated; what role can light play in valuing parks; how can lighting help attract more people to the gardens in the evening; what kind of lighting can provide a feeling of security for residents while at the same time protecting the environment and the starry sky, etc.

The design competition was organized in two phases. The first phase aimed to identify participants whose previous professional experience and approach suited the competition. In the second phase, three participants were invited to submit a full competition entry based on the submitted portfolios and team CVs. The competition winner was awarded a prize of 8,000 € (plus a contract with the value of 7,000 € for creating the Kanuti Garden sketch project), while the two remaining works were awarded a prize of 6,000 € each.

The jury chose the work "Echoes" by Finnish VALOA Design Ltd. According to the jury members, they provided a holistic concept and the most innovative ideas. The team of VALOA Design suggested customized wooden poles, which creates a connection between all Bastion Zone parks and give a unique appearance that plays in harmony with the whispering light of bastion walls and towers. VALOA Design also suggested an intelligent control system that takes weather, time, seasons, and even bats into account.

Figure 40. Lighting visualization for Canute Garden by VALOA Design Ltd.

Based on VALOA Ltd's lighting schematic design, the electrical design for the realization of the lighting solution at Canute Garden Park was done by Leonhard Weiss OÜ.

6.1.4 Construction

As a result of construction procurement, Mefab OÜ was awarded the contract. The construction was realized according to plan, and most works were completed on time. A delay of 4 weeks was introduced due to the extended delivery time of procured luminaires.

The most significant challenge in the construction process was the control system, as it was the first weather-based lighting control system installed in Estonia thus far. Although a more straightforward alternative would have been to use data received from weather stations, it was decided to use a more accurate and reliable solution by covering the pathway with local sensors. The same system was already used for road maintenance purposes but never to control luminaires.

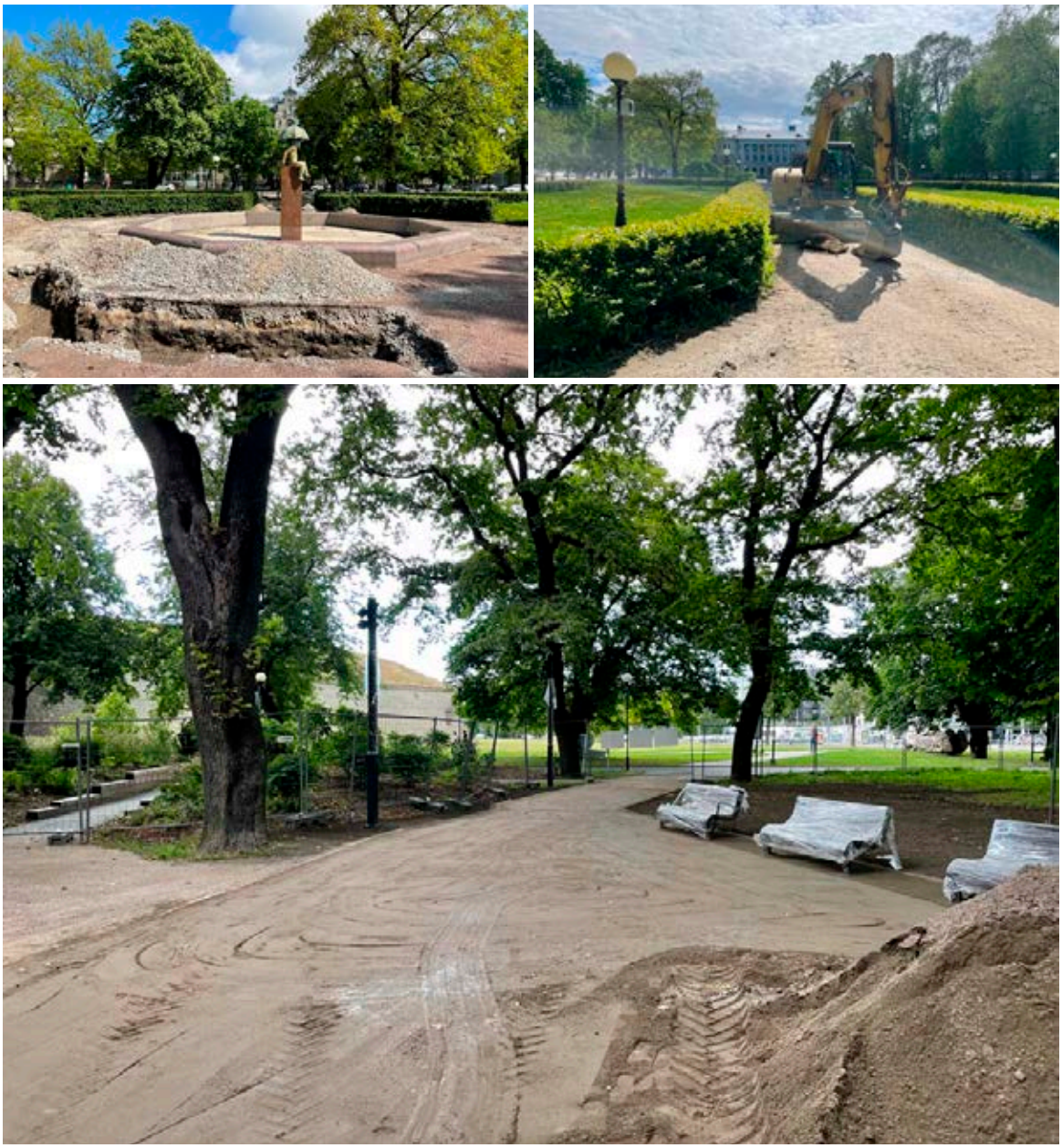


Figure 41. Construction works at the LUCIA pilot site in Tallinn (all photos provided by Tallinn City Government).

6.2 Pilot site evaluation

The aspects that were determined to be more relevant for the Tallinn pilot site were used to assess the success of the constructed pilot site. Based on the identified more pertinent aspects of the Tallinn pilot site, evaluation activities were carried out to evaluate the situation at the pilot site before and after the completion of the pilot project (see Table 13).

TABLE 13. EVALUATION OF MORE RELEVANT ASPECTS OF THE TALLINN PILOT SITE BEFORE AND AFTER PROJECT LUCIA.

CRITERIA	STATUS AT PILOT SITE BEFORE PILOT PROJECT	STATUS AT PILOT SITE AFTER PILOT PROJECT
Safety	Low feeling of safety.	New park lighting makes people feel good, good quality lighting, more light in the entire park, illuminated horizon (facades, trees).
Energy efficiency	Annual energy consumption of 11 120 kW, with an average of 300 kWh per luminaire.	Annual energy consumption of 5 894 kWh, with an average of 80 kWh per luminaire.
Creativity	Only functional lighting	Decorative lighting added, RGBW fountain lighting and seasonal light art installations
Public opinion	The park had a bad reputation and was underused.	A wholly changed atmosphere during darker times of the year. Seasonal art and creative lighting for the fountain encourage spending time in the park.

Safety aspects were researched using crime data from the Police Department and citizen opinions through a public questionary. Crime data and citizen opinion showed that Canute Garden was not a safe park to be in the evenings. The Tallinn team of LUCIA considered the safety problem in the design process and used seminar workshops and public questionary results. The identified keywords for lighting solutions to feel safe include: good quality lighting, high colour rendering index (CRI), bright horizon, no blinding, more lighting in the entire park. Gathering public feedback on safety is an ongoing process, but first opinions have been positive, and it looks that if lighting makes you feel good, it also means that you feel safe. Because of seasonal light art installations, more people visit the park during dark hours, and more people also means a more secure feeling.

Energy efficiency was calculated using technical data and the amount of old and new luminaires (see Table 14). Only the area illuminated before the LUCIA project was considered when comparing energy efficiency. Since the LUCIA pilot included the lighting of additional regions (fountain, sculpture, playground, new sitting areas, nearby facades), the total energy consumption of the pilot site was increased to 3,343 W (159 LED luminaires). The increased energy is required to improve safety in the park, and although total energy consumption has increased, the total energy used for lighting the area illuminated before has decreased.

Read more about the importance of power quality

Each pilot sought to increase energy efficiency, but none discussed power quality aspects, which significantly impact overall energy efficiency [23].

TABLE 14. SUMMARY OF TECHNICAL PARAMETERS OF OLD AND NEW LUMINAIRES OF THE LUCIA TALLINN PILOT SITE.

	LUMINAIRE	LUMINOUS FLUX (LM)	POWER CONSUMPTION (W)	COLOR TEMP. (K)	CRI	LUMINAIRES (PCS)	TOTAL POWER CONSUMPTION (W)
Old	Glob 70W sodium	5500	70	2000	20	37	**2590**
New	LED lamp	1476	15	3000	80	64	960
	LED lamp	3250	34	3000	90	7	238
							1198

Weather conditions are used to control the lighting system. The lights are dimmed to 70% during dry weather and paths and 50% with snow. During rainy weather and wet surfaces, lighting is set to work at 100% output. As a result, the average power consumption is less than before, even with additional lights installed.

Custom-made products, special fountain lighting, seasonal light art installations, and low, intimate lighting complement the originality of the park. The new lighting solution of the park is entirely different from the previous one. It considers nature, night-sky, and people's emotions while the old system focused merely on functionality.

Public opinion about Canute Garden was terrible because of the past incidents with hooligans. The mentioned problems were solved long ago, but the lousy reputation stayed. Tallinn has had the chance to question people during the Light Festival, held on 16-18.09.2021, and the first impressions about the park's new look were excellent.

6.3 Summary

The pilot project started at the beginning of 2019 with planning and co-creation events until 2020. Another year (2020) was spent on the design process, followed by six months of construction. The pilot site was completed on 24.09.2021. The realization of the pilot allowed the City of Tallinn to involve the public and investigate innovative technologies and GPP guidelines to create a meaningful place for residents and tourists in the evenings.

The realization of the Pilot site was successful as the City of Tallinn achieved the goals they set for themselves. Almost every keyword from co-creation events about the desired lighting was addressed. People wanted calm and cosy lighting and asked to avoid light pollution and colourful lighting and preserve the ecosystem and night sky. The new lighting system is energy efficient, provides glare-free and comfortable lighting, is controlled by a weather-based control system, and considers nesting periods of birds.

Figure 42. LUCIA project pilot site in the City of Tallinn
(photo upper left by Tarmo Korõtko, upper right and bottom by Hannes Vega).

Summary of LUCIA pilot sites

Dynamic lighting was demonstrated on roads and bicycle lanes at **Albertslund** at the DOLL Living Lab. The pilot site includes solutions for pedestrians, bicyclists, and cars to increase energy efficiency and provide increased safety and comfort for a better and calmer traffic flow. The pilot was realized in steps, where market dialogues were conducted to find the most relevant dynamic lighting solutions providers.

Figure 43. LUCIA pilot site at Albertslund (photo provided by DOLL Living Lab).

The pilot site of **Hamburg** Altona includes a narrow pedestrian and cyclist street and tunnel. The redesigned pathway features 29 new luminaires along the trail and six new lights placed inside the tunnel. Numerous co-creation events were carried out in different formats by the Municipality to ensure the residents were involved in the planning process of public lighting at the pilot site.
The planning of public lighting requires a sophisticated lighting plan or lighting hierarchy to consider the needs of pedestrians, cyclists, residents, insects, animals, and other environmental requirements.

Figure 44. LUCIA pilot site at Hamburg Altona (photo provided by Bezirksamt Altona).

The **Jurmala** pilot site improved lighting on a 1 km strip of Jomas street. The replaced luminaires, dimmers and motion sensor-based control with DALI communication improved overall energy efficiency by over 40%. These improvements were planned and designed in cooperation with local businesses and residents to suit their needs. As a result, the visitors of Jurmala can enjoy the aesthetics of the city, while residents and local businesses can say they shaped the city's public spaces to increase overall well-being and contribute to a sustainable future.

Figure 45. LUCIA pilot site at Jurmala (photo provided by Jurmala City Administration).

The LUCIA pilot site in **Porvoo** delivered intelligent and energy-efficient lighting to a pedestrian route along the Porvoo river. The illuminated pedestrian route does provide not only comfort but also a sense of security. The lighting design process included different co-creation activities and the implementation of their results. Different multi-functional installations were installed with the lighting system, including sound beacons for the visually impaired, lighting poles with solar panels, gobo projectors for road signs, etc. In the future, the Länsiranta area will serve all residents, guests, and tourists in a magnificent recreation area offering a wide range of services and technology.

Figure 46. LUCIA pilot site at Porvoo (photo by Tarmo Korõtko).

A multifunctional and intelligent lighting system was constructed at the LUCIA **Saint Petersburg** pilot site at SPbPU, which comprised 25 lighting poles with LED luminaires, a modern control system, video surveillance equipment, and wireless Internet access points. The knowledge and experience received by SPbPU experts during the project are disseminated to the entire campus.

Figure 47. LUCIA pilot site at St. Petersburg (photo provided by SPbPU).

The **Tallinn** pilot site was about creating a park of seasons, where the light changes according to the time of the year by using different possibilities of modern lighting. There was also social ambition: bringing life into the park during darer hours. The Park is a cultural heritage asset, and the lighting was renewed to create harmony with the lights of the nearby Old Town city walls and towers. The realization of the pilot allowed the City of Tallinn to involve people, study innovative technologies and GPP guidelines. The installed lighting system is energy efficient, provides glare-free and comfortable lighting, is controlled by a weather-based control system, and considers nesting periods of birds.

Figure 48. LUCIA pilot site at Tallinn (photo by Tarmo Korõtko).

Concluding remarks

This second volume of the LUCIA Compendium has described the realisation of six pilot sites in the cities of Albertslund (Denmark), Hamburg (Germany), Jūrmala (Latvia), Porvoo (Finland), Saint Petersburg (Russia), and Tallinn (Estonia). The individual experiences of each municipality are summarized within this document to guide and encourage other cities of the BSR and other regions to replicate the piloted solutions. By realising the pilot sites, the participating municipalities could apply the theoretical technological, economic, and societal aspects of smart urban lighting in practice, which has been the focal point of project LUCIA.

Contacts

Lead Partner

Free and Hanseatic City of Hamburg, Borough of Altona
Heike Bunte
heike.bunte@altona.hamburg.de, tel. +49 40 428 116 250

Thomas Jacob, Senate Chancellery Hamburg
thomas.jacob@sk.hamburg.de, tel. +49 40 428 312 656

Pilot Site Coordinator

Tallinn University of Technology
Tarmo Korõtko
tarmo.korotko@taltech.ee, tel. +372 522 1510

References

[1] H. Bunte, T. Jacob, T. Haapanen, S. Enevold and Y. Le Moullec, "LUCIA COMPENDIUM vol. 1: Sustainable and Smart Urban Lighting," Tallinn University of Technology, 2020.

[2] LUCIA – Lighting The Baltic Sea Region, "Planning and Procurement Factsheet: Private and public sectors as equal development partners," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/02/LUCIA-factsheet-1-__-PPI-contract__FINAL.pdf.

[3] T. Haapanen and J. Myllyluoma, "Local expert workshops – economic aspects of smart urban lighting," 2019. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2019/12/lucia__local__expert__workshops__summary__report.pdf.

[4] J. Myllyluoma, C. L. Orta and J. Tvrdý, "Assessment of economic aspects of smart urban lighting systems in selected pilot areas around the Baltic Sea," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/02/LUCIA__WP2__GoA-2.2__FINAL__REPORT.pdf.

[5] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: Supporting technologies – the key to smart lighting," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-5-20-03-25.pdf.

[6] H. Bunte and R. Jurgesa, "Co-creating lighting solutions – Lessons learned report," 2021. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/07/LUCIA-lessons-learned-report__June-2021__co-creating-urban-lighting-solutions__web-version.pdf.

[7] LUCIA – Lighting The Baltic Sea Region, "Social Acceptance Factsheet: Light pollution affects biodiversity," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-SFS-2-20-03-25.pdf.

[8] LUCIA – Lighting The Baltic Sea Region, "Social Acceptance Factsheet: Preserving darkness in the city," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-SFS-3-20-03-25.pdf.

[9] LUCIA – Lighting The Baltic Sea Region, "Planning and Procurement Factsheet: EU Green Public Procurement (GPP) guidelines on road lighting," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/02/LUCIA-factsheet-3-__GPP-road-lighting-introduction__FINAL.pdf.

[10] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: The need for lighting system verification measurement," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-6-20-03-25.pdf.

[11] LUCIA – Lighting The Baltic Sea Region, "Social Acceptance Factsheet: Can lighting reduce vandalism? Protecting public property from damage," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-SFS-4-20-03-25.pdf.

[12] LUCIA – Lighting The Baltic Sea Region, "Social Acceptance Factsheet: Creating a "lighting hierarchy"," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-SFS-1-20-03-25.pdf.

[13] LUCIA – Lighting The Baltic Sea Region, "Economy Factsheet: How to finance smart urban lighting investments," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-EFS-2-20-03-25.pdf.

[14] A. Rosin and R. Ahmadiahangar, "Technology – state of the art," 2019. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/04/LUCIA__technology__state__of__the__art__report__190826.pdf.

[15] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: What to consider in designing a lighting control system," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-1-20-03-25.pdf.

[16] LUCIA – Lighting The Baltic Sea Region, "Economy Factsheet: Applying a life-cycle approach to smart urban lighting investment decisions," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-EFS-3-20-03-25.pdf.

[17] LUCIA – Lighting The Baltic Sea Region, "Social Acceptance Factsheet: The role of the private sector in public lighting planning," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-SFS-5-20-03-25.pdf.

[18] LUCIA – Lighting The Baltic Sea Region, "Planning and Procurement Factsheet: How to get started – Going Green in Public Procurement," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/02/LUCIA-factsheet-4-__Going-green-in-Public-Procurements__FINAL.pdf.

[19] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: Energy efficiency and luminous efficacy of LEDification," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-2-20-03-25.pdf.

[20] LUCIA – Lighting The Baltic Sea Region, "Economy Factsheet: Economic benefits of multi-functional smart urban lighting," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-EFS-4-20-03-25.pdf.

[21] H. Bunte and T. Vollmann, "Documentation of the LUCIA mid-term webinar series," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/12/201209__Documentation__LUCIA-mid-term-webinar-series.pdf.

[22] LUCIA – Lighting The Baltic Sea Region, "Planning and Procurement Factsheet: Making your procurements more sustainable," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/02/LUCIA-factsheet-2-__sustainable-purchase__FINAL.pdf.

[23] LUCIA – Lighting The Baltic Sea Region, "Planning and Procurement Factsheet: Key criteria for a green lighting system," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2021/02/LUCIA-factsheet-5-_Key-criteria-in-Green-Public-Procurements_FINAL.pdf.

[24] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: The importance of power quality," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-4-20-03-25.pdf.

[25] LUCIA – Lighting The Baltic Sea Region, "Economy Factsheet: Key strategies to link economic development and smart urban lighting," 2020. [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-EFS-1-20-03-25.pdf.

[26] LUCIA – Lighting The Baltic Sea Region, "Technology Factsheet: Improving the reliability of lighting systems," [Online]. Available: https://lucia-project.eu/wp-content/uploads/2020/03/LUCIA-factsheet-TFS-3-20-03-25.pdf.

The LUCIA project provides municipalities with up-to-date knowledge of energy efficient urban lighting, covering aspects of environment, technology, economy and social acceptance. To provide a tangible experience of its potential, innovative and energy efficient lighting solutions are installed in six cities across the Baltic Sea region.

Project budget: € 3.12 million
Project lifetime: 2019–2021

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