Lighting design for green areas, in the study case of Utterslev Mose

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Abstract:

"How to design a lighting system for Utterslev Mose to improve the lighting efficiency while covering citizens needs and considering wildlife?"

The lighting design for green areas in the study case of Utterslev Mose designs a lighting system and it proposes a lighting concept for this specific green area. It carries out an analysis of the current lighting systems of five green areas from Copenhagen and Fred- eriksberg municipalities. The analysis' results are used as a guidance on the design phase of this project. The global concept for the design supports nature by enhancing the nature colours in each season and bringing an smooth colour transition through the year Utterslev Mose will be illumianted with the colour of flowers. The lighting system is based on the mentioned concept and it consist of an intelligent lighting that sent commands to luminar- ies via wireless transmission. The luminaries will change colour through out the year at the same speed than seasons. Luminaries are grouped in three blocks that correspond the three areas that crate the three lakes.

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1. ABSTRACT

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2. INTRODUCTION

2.1 Topic

Located in Northern Europe, Copenhagen is recognized as one of the most environmentally friendly cities in the world. It is a growing metropolis with an ambitious approach to urban planning and green living. The city aims to become carbon-neutral by 2025, where the city planning, streets and squares, are to be designed to encourage cycling as the favoured transport and it boasts large recreational areas.

Nature merges in the city, as the city merges into nature. This harmonic combination can be easily observed from the amount of parks that the city offers to its inhabitants. King's Garden (Kongens Have), the garden of Rosenborg Castle, the Botanical Gardens, Fælledparken, Østre Anlæg, Frederiksberg Gardens, Langelinie, etc., and a long list of cemeteries that copenhageners use as parks. Green areas are considered an important element for the capital, which appoint them as the lungs of the city. Copenhagen promote keeping parks clean and in good conditions in order to invite its citizens to enjoy activities surrounded by nature.

Observing the green areas outside of the metropolitan area, on the surroundings of the city, is possible to find a large semi-natural area of lakes, reed beds and parkland called Utterslev Mose. It is located on the border between Gladsaxe and Copenhagen municipality. Utterslev Mose is known for its rich bird life and has a dense network of walking and cycling trails, which thousands of people enjoy every year. It is one of the biggest green areas in Copenhagen municipality.

As a Scandinavian city, the number of daylight hours in Copenhagen varies considerably between summer and winter solstice. This geographical fact challenge the city to not limit its citizens' activities because of the lack of daylight in winter time. In spite of the municipality's effort in supplying all their best services to the citizens, still there are some of the mentioned green areas without any type of lighting system, limiting the number of outdoor activities during winter time.

Copenhagen has a Lighting Masterplan "Belysningsmasterplan"(1) which based on the lighting strategy for Copenhagen, "The night in the City of Lights" (2) provide the basis for a major renewal project approved by the City Council in December 2013. Although there is this lighting masterplan, which has detailed improvements for lighting in green areas, there is no plan for a lighting system at Utterlsev Mose.

2.2. Study Case Utterslev Mose

Observing the relationship between green areas and copenhageners, lighting design for green areas became an interesting topic, in order to study how the different lighting techniques are used in Copenhagen. This, combined with the lack of lighting system at Utersslev Mose and the Copenhagen interested in achieving a higher engagement between people and nature, made Utersslev Mose an exciting case to study.

A lighting system at Utterslev Mose would offer to its users an extension of the amount of hours that people can practice outdoor activities during winter time. This would increase the quality of life since people is not limited to daylight and they would feel comfortable when walking throughout nature during night time, compare to the existing situation.

2.3. Purpose

The goal of this project is to design an interactive lighting system proposal that it is efficient, consider the wildlife and reinforces people engagement in nature prolonging the amount of hours that citizens can spend in nature during winter time.

The initial idea was to address the lighting design concept with an innovative solution that incorporates new technologies, taking inspiration from Søndermarken (Frederiksberg). Søndermakren combines lighting and technology serving users with an interactive system that gives the possibility to set a running pace to complete the whole route with the desired timing. The system guides runners with flashing light through the whole circuit. A similar solution could be implemented as a playful tool with high potential for this study case, if the qualitative research indicates this type of technology is relevant in green areas.

The lighting system should follow an organic design and create an atmosphere according to the space. The main goal is to encourage people to use green areas and appreciate nature. Furthermore, this lighting design would help in the process of leading cycling as the main transport by 2025, by offering facilities to walk and bike through Utterslev Mose paths while creating an enjoyable atmosphere to copenhageners.

2.4. Statement

Considering what is mentioned in the previous sections, the following statement was set. The study of the existing lighting techniques in green areas of the city of Copenhagen, can guide to:

How to design a lighting system for Utterslev Mose to improve the lighting efficiency while covering citizens needs and considering wildlife?

3. METHODOLOGY

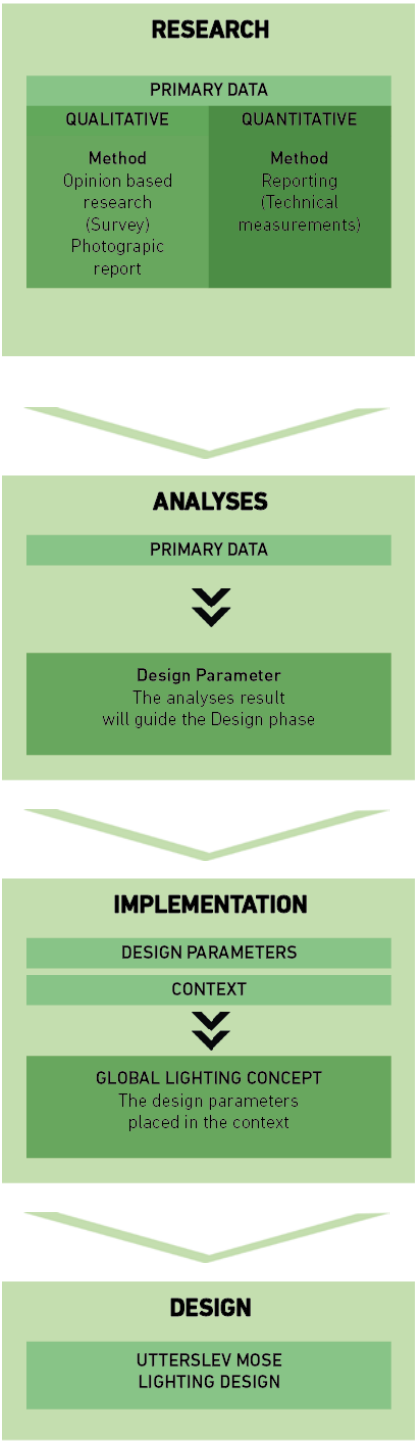
In this section it is explained the procedure that this study will follow in order to approach the statement formulated in the Statement section. (2.4 Statement)

The study will be divided in a primary data collection, which will content a qualitative and quantitative research made on-side, to gather information from each of the green areas to study. From there, a lighting system will be design for Utterslev Mose.

The primary data collection encloses a qualitative research following an opinion based research method where, throughout a survey in each green area, people will provide information about their feelings and thoughts about the lighting system. Moreover a quantitative research based on reporting method will completed the primary data block with photography report and lighting measurements.

Previous to design phase, it is necessary to gather information from existing lighting system in green areas to study the different lighting techniques used inside the Storkøbenhavn areal. This technical information will contemplate the type of source, type of luminaries, the distance between each fixture, power consumption, efficiency and the Lux measurements that luminaries provide during night time on horizontal axis, the ground surface, and on vertical axis, on a height that can simulate people's faces. The analyses of that information together with a photographic report, for obtaining visual information of the context, it should give as a result the characteristics of an efficient lighting technique for the design phase.

The results from the analyses of the primary data will be the tools to guide the lighting design for Utterslev Mose.



4. GREEN AREAS IN THE STUDY

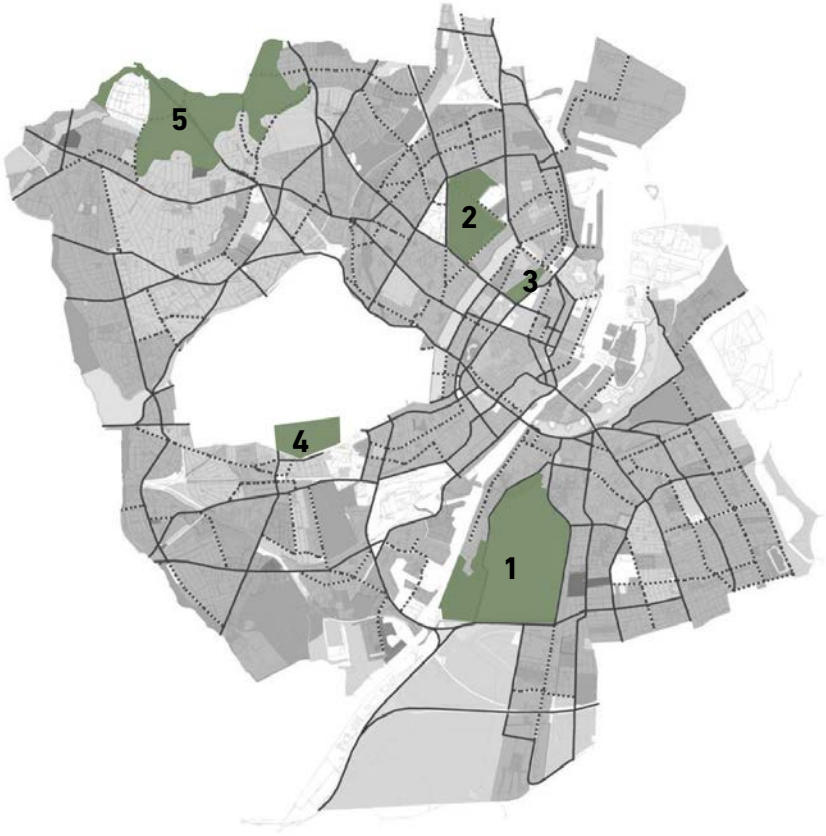
Previous to the information gathered through out the methods mentioned in the previous section, a breve introduction will show the location and it will explain the similarities of the areas selected.

Figure 2. Municipalities of Copenhagen and Frederiksberg.

The list of the green areas where primary data collection will take place is: Amagerfælled, Fælledparken, Østre Anlæg, Søndermarken and Utterslev Mose. The decision of the selected areas to study is based on the similar features of each area to Utterselv Mose and , furthermore, it also consider green areas that use new technologies like interactive lighting system, as Søndermarken. The number of parks is limited to 5 due the limited time up to 3 months to carry out the project and the amount of green areas in the city. (Figure 1: Areas location)

4.1 Location

The green areas studied in this project are located inside Copenhagen municipality, except Søndermarken which is under Frederiksberg area. (See Figure 2) The reason why it was decided to include it in the project was due its innovative and interactive lighting system, which could be a relevant influence in the final design for Utterslev Mose lighting system. (Information about the interactive system in secction 5.4 Søndermarken)



1 Amagerfælled
2 Fælledparken
3 Østre Anlæg
4 Søndermarken
5 Utterslev Mose

Figure 1. Location of the green areas

4.2 Areas Comparison

The green areas of this study were selected in the early steps following four parameters: location, wildlife, activities and innovative technology.

Utterslev Mose is a green semi-natural area located on the surrounding of the city at the border of Copenhagen municipality. Following the same peculiarity of being located outside of the city, Amagerfælled was selected to be part of the project. Comparing this area with Utterslev Mose, it is also rich in wildlife and have similar dimensions.

Fælledparken and Østre Anlæg were selected in order to compare if there is used a different lighting technique when green areas are located at the inner city or outside of the city. Another feature that Fælledparken share with Utterslev Mose is a high flow of users practicing several sports as: running, soccer training, matches on the courts marked on the grass, playgrounds, as well as being an area with a high variety of animals and plans. For example, the nature in Fælledparked is characterized for having approximately 200 marsh frogs (Figure 3)

The interactive lighting system that offers Søndermarken makes from it a green area to refer when approaching the lighting design for Utterslev Mose using new technologies and attracting users.

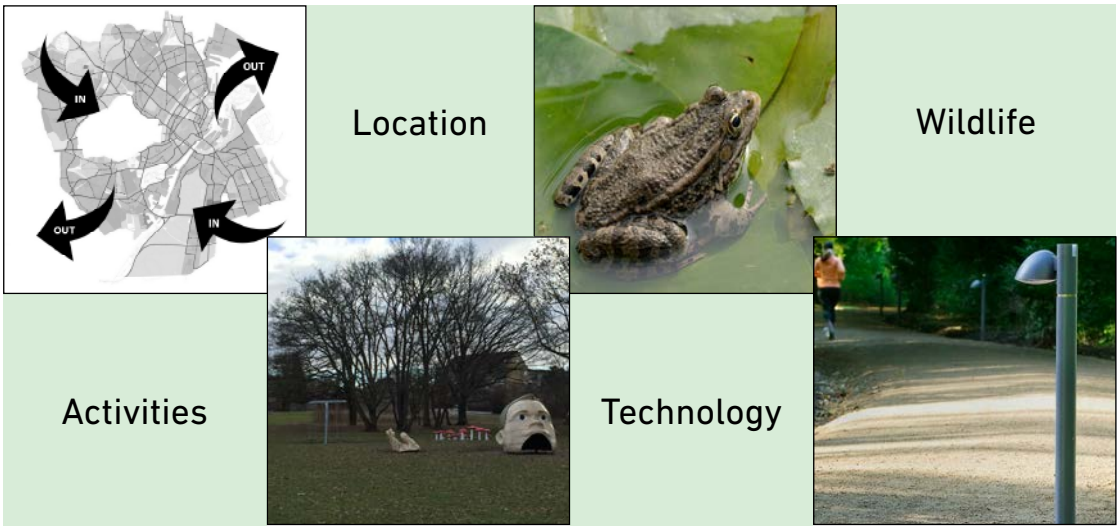


Figure 3. Features for selection of areas

5. PRIMARY DATA

This chapter collects the methods used in this study to gather information through a qualitative and quantitative research. (See figure 4)

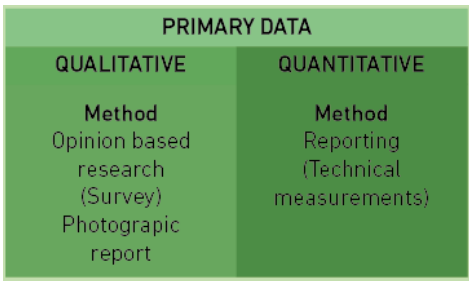


Figure 4. Primary data division

As previously mentioned on section Methodology (see 3.Methodoogy of this study) the qualitative research it is done individually for each green area following an opinion based research and a photographic report.

A side of the qualitative research, a quantitative research and its analyses complete the primary data of this chapter by taking technical measurements on side.

5.1. METHODS

This section explains the specific methods by which the research data is collected and the specific research techniques that will be used to answer the problem formulation statement.

QUALITATIVE RESEARCH

The qualitative research will allow to obtain an overview of the context of each green area and the opinion of the users regarding facilities, lighting system and what they think that can be improved. A photographic report of each area, in conjunction with a survey on-side, will allow to gather all this information.

The unavailability of a camera machine and an overbooking on the equipment from the Aalborg University booking system, leaded the author of this study to carry out the photographic report by using the camera of an Iphone 6. Using this solution it will allowed to record videos at each green area in order to produce, in a future steps, the video required on the thesis specification hand-in document. The technical specifications can be seen in Table 1.(Table 1. Camera and video characteristics)

Camera characteristics:	Video characteristics:
ƒ/2.2 aperture HDR image 8-megapixel iSight camera with 1.5µ pixels Exposure control Panorama (up to 43 megapixels)	1080p HD video recording (30 fps or 60 fps) Slo-mo video (120 fps or 240 fps) Time-lapse video with stabilization Cinematic video stabilization Continuous autofocus video 3x zoom

Table 1. Camera and video characteristics

In order to complete the qualitative research, 30 users from each green area will be asked to fill up a survey questionnaire using SurveyMonkey platform [1]. The survey target group is people that had been in the area at least once and they can contribute with real and valuable information when approaching the problem formulation. (See Annex1.Survey Questionnaire)

The survey answers will be analysed statistically to figure out the main user of each area. Furthermore, from the results it will be collected a list of excising problems and improvements according to people's opinion. This information can be used as a design tool when designing the lighting system for Utterslev Mose.

QUANTITATIVE RESEARCH

The quantitative research will complement the previous material with technical information of type of source, type of luminaries, distance between fixtures, power consumption, efficiency and Lux measurements on horizontal axis, on ground level, and on vertical axis, on a height of 1.75 (the average height of Danish citizens). This data will let to analyse the different lighting techniques used by observing how the distance between luminaries, height and intensity, effects on the lighting distribution to figure out which technique can offer a better solution for the Utterslev Mose lighting design.

The qualitative and quantitative research should concede a basis for an efficient lighting technique that cover users' needs and guide the design to create an atmosphere according to the context.

PROCEDURE

The next pages present the qualitative and quantitative research with a brief introduction for each green area. Following each introduction there is a photographic report and a survey's analyses. The information is completed with the technical measurements which are analysed in diagrams. To analysis end with a technical sheet summing up the relevant information from each area and a table to compare all the different luminaries and techniques.

5.1 AMAGERFÆLLED

Amagerfælled is a green area located on the south of Copenhagen in Amager district. (See Figure 5). It accounts for 223 ha where people can practice a wide range of activities: outdoor pursuits, running, picnics, bonfires, hang-gliding, model flying, BMX biking, cycling, horse riding, fishing, berry picking, sunbathing, ball games and hiking. The following image shows the map of the green area and located on it the zones for each activity (Figure 6). Furthermore, It specifies the path types and curiosities of the area.

Figure 5. Green zone reefers to Amagerfælled location in the Copenhagen areal

Figure 6. Map of the Amageræelled

AMAGERFÆLLED photographic report

Figure 7. Route of the photographic report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AMAGERFÆLLED ANALYSES photographic report

EXPERIENCE

The expedition to Amagerfælled permit to experience the feelings when being in the green area. Carrying out the photographic report it also allowed to observe how users experience the place.

It is a huge area where some zones look quite empty, giving a sensation of missing some trees and nature around. The impression of emptiness is not inviting people to walk or chill around the place and it can be perceived on pictures number 4 and number 8 from the photographic report.

Furthermore, Amagerfælled accommodates *Island of Love - Kærlighedsøen*, an art instalation from the artist Bjørn Nørgaardcareless. It is a circular artificial structure where a roof with lead mounted handblown colored glas paints the ground in different colours in a sunny day, and during night time lights from the ground lit up the roof enhancing the colourful structure. Even this installation is part of the area , the surroundings of it leads to a feeling of careless, including the art installation which shows a deteriorated appearance. (See Picture 16 on the photographic report)

LIGHTING SYSTEM

During the process of undertaking pictures at Amagerfælled no lighting system was found in the whole green area. Even there is lighting on the traffic roads around the area, non of the inner paths of the park present any lighting system, including the main paths (paths shown in red line on the map in Figure 6).

However, there are some zones in the area where a lighting system could be relevant for helping people to do their tasks ,as for example the grill area, which currently it not enabled people to use it during night time (see picture 14)

RELEVANT FOR THE DESIGN:
- Avoid a careless feeling in the area.
- It is interesting to enhance nature.
- If there is any art or sculpture in the zone , make it part of the green area.

AMAGERFÆLLED Survey

A survey was carried out on the 7th and 8th of march of 2016 at Amagerfælled. Users from the area were taking a survey of 10 questions with 2 open questions.

Questions of the survey can be found at chapter 9.1 Survey Questionaire

AMAGERFÆLLED ANALYSES Survey

Carrying a survey was helpful in order to obtain relevant information from users of the area. From the results its possible to observe that the main group using the area is people between 35 and 44 years old with a frequency of either 4 times per week or 2 times per week. The major activity is walking, followed by people who likes running in the green area. The results also show how people mainly use the area during day time, specially between 8am and 3pm, fact that can be due the lighting conditions since all of them coincide on a poor lighting and unsafe feeling during night time. The majority of the users do not know about the existence of the interactive lighting system in Søndermarken, however they think that it must be an enjoyable tool.

Regarding the open questions about inputs for improving the area and observations, users seem to have an strong dependence of the daylight when going to the green area and the majority of them demand for a lighting system, since it will facilitate they journey to work when crossing the area or increase the hours that they can go there for a walk. Some people also focus on nature and the appearance of the area demanding more vegetation, as well as, a high demand on increasing the playgrounds for kids.

To conclude the survey analyses, Amagerfælled can be described as an area with high vulnerability to light pollution due its biodiversity and a place to experience nature. However some citizens expressed desire for better illumination of the path connections.

RELEVANT FOR THE DESIGN:
- People like to use the park to chill and running.
- No lighting lead people to feel unsafe in the area, using it only during day time.
- Playgrounds for kids are in demand.

AMAGERFÆLLED technical measurements

Due the absence of lighting in Amagerfælled the lighting measurements of this green area are ignored leading an invalid quantitative research for this area. However, the qualitative research will be taken into account for further steps in the design process.

Nonetheless, the Lighting Masterplan of Copenhagen [2] consider a lighting system for Amagerfælled. According to the plan, an asymmetric lighting system will lit the main paths that cross the area and it will guide cyclist and pedestrians with bollards luminaries. Due the dimensions of the park, the plan specifies that the luminaries will use a reddish colour temperature in order to minimize the impact in nature since this area host a wide range of wildlife. The following images show the outline of the lighting system.

5.2 FÆLLEDPARKEN

Fælledparken is a green area located in the inner city of Copenahgen (See Figure 8). The park has an oasis on its 58ha of green area. People can practice a wide range of activities at Fælledparken like: walking, running, picnics, soccer training and matches on the courts marked on the grass, sunbathing, concerts and celebrations such as carnival. The following image (Figure 9) shows the map of the green area and located on it the zones for each activity.

Figure 8. Green zone reefers to Amagerfælled location in the Copenhagen areal

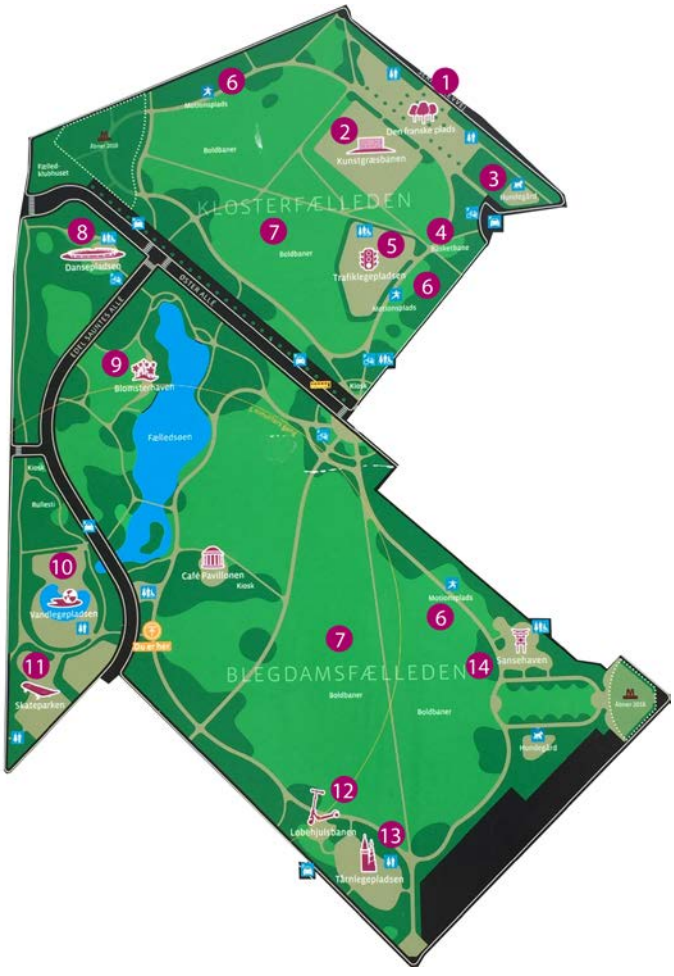


Figure 9. Map of Fælledparken

FÆLLEDPARKEN photographic report

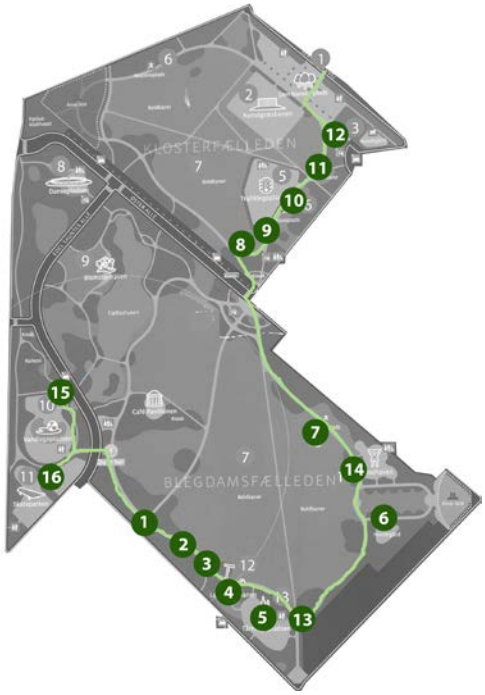
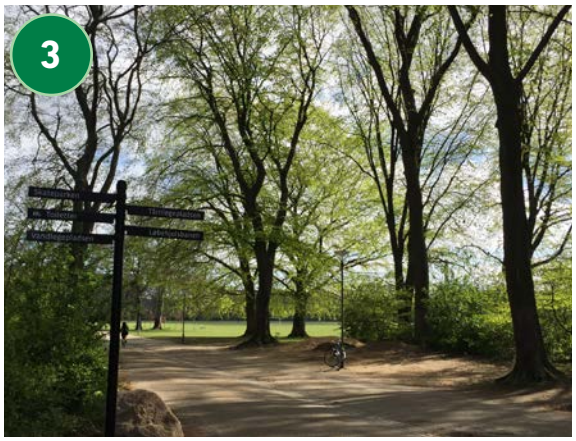


Figure 10. Route of the photographic report

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FÆLLEDPARKEN ANALYSES photographic report

EXPERIENCE

Movement and action, at the same time that there is calm and silence. On one side, people walking and chilling, on the other side, football matches taking place. This define Fælledparken. As mention at the introduction of this section, Fælledparken is a park in the inner city and you can easily experience it when you walk through its paths. There is movement, of course, It is in the city, but at the same time is peaceful. Its dimensions permits to copenhageners to find in it a place for a wide range of activities.

When citizens are in the park, they can easily see how the city hall takes care of It and how good is Its design, which take care about citizens from all ages, animals and plans. Even though, it is a green area of considerable dimensions, people still can find cosy areas to disconnect from the city.

At night, Fælledparken becomes quiet and the silence covers the area. Even though It is night time, the park still looks safe and gives a comfortable feeling to who is having a late ride in nature.

LIGHTING SYSTEM

The photographic report of Fælledparken allowed to observe in a first sight, how the green area is lightened. The lighting covers the peripheral pathways using bollards, which give the chance to citizens to walk around the area during night time. Furthermore, there is lighting in specific zones when it is required, as for example a football court if a football team is training.

The lighting combines bollard and mast luminaires and Its strategy perseveres the wildlife keeping dark zones and not lighting all of the paths. The usage of bollard luminaires permit to focus the lighting on pathways avoiding that the light distribution reaches the surroundings.

Although the lighting system follows the mentioned lighting strategy, there are some zones in the area where to locate extra luminaries it could be relevant for users, as for example the transversal paths, which currently do not present a lighting system. (see photography 13 on the photographic report), as well as some of the playgrounds. (see photography 5 and 14)

RELEVANT FOR THE DESIGN:
- The combination of active and chill areas add dynamism to the park
- The lighting increase the safety feeling at night.
- Usage of different type of luminaries depending on function
- Leave areas without lighting to preserve wildlife.

FÆLLEDPARKEN Survey

A survey was carried out on the 9th and 10th of march of 2016 at Fælledparken. Users of the area were taking a survey of 10 questions with 2 open questions in it.
For the questionnaire see chapter 9.1.Survey

FÆLLEDPARKEN ANALYSES Survey

The results show that there is not a clear main age user group, since the percentage is quite even. People from all ages use the park, but there is a high percentage that use the park for running and training.

The time of the day when the park is used in a higher frequency is between 3pm and 6pm, and users go to the park with an average of three times per week. The lighting system in the park allow to increase the percentage of users during night time, who affirm that the lighting system in the park open more possibilities to citizens.

Regarding the interactive lighting, 70% of the people who took the survey knew about the existence of an intelligent lighting in Søndermarken. However, only 10% used it more than two times since they find it a good tool to improve their trainings.

From the open questions it was registered that even though there is lighting the quality of it is not good enough for people who is running. Users were pointing that the park offers a wide range of possibilities and that is really good for the city , but they think that It is important to improve the amount of toilets and places for drinking. Some people, as in Amagerfælled focus on nature demanding more variety on the type of plants and flowers in the area.

RELEVANT FOR THE DESIGN:
- A good public park must be designed for people from all ages.
- The lighting allow citizens to enjoy nature at night.
- People like biodiversity.

FÆLLEDPARKEN technical measurements

This section present the luminaries used in Fælledparken and it specifies where are located. A posteriori, illuminance measurements are visualized and analysed by diagrams.

LUMINAIRES

Fælledparken use different lighting for different functions. For example, at the entrances of the park there are placed mast luminaries, which increase the amount of light at the entrance inviting people to come into the park, at the same time that make them feel safety This type of luminaire are in the Copenhagen Lighting Masterplan under the category class of ***Residential and Pedestrian [2]***. However to lit the surrounding pathway It was choosen bollards luminaires, ,which focus the lighting distribution on the pathway avoiding to lit the surroundings in order to preserve the wildlife.

Figure 11. Fælledparken lighting

TYPE OF LUMINARIES

Philips Park armature

ERCO Panorama IP65 floor washing.

Uplight Accent lighitng

High masts with downward spotlighting, sport courts.

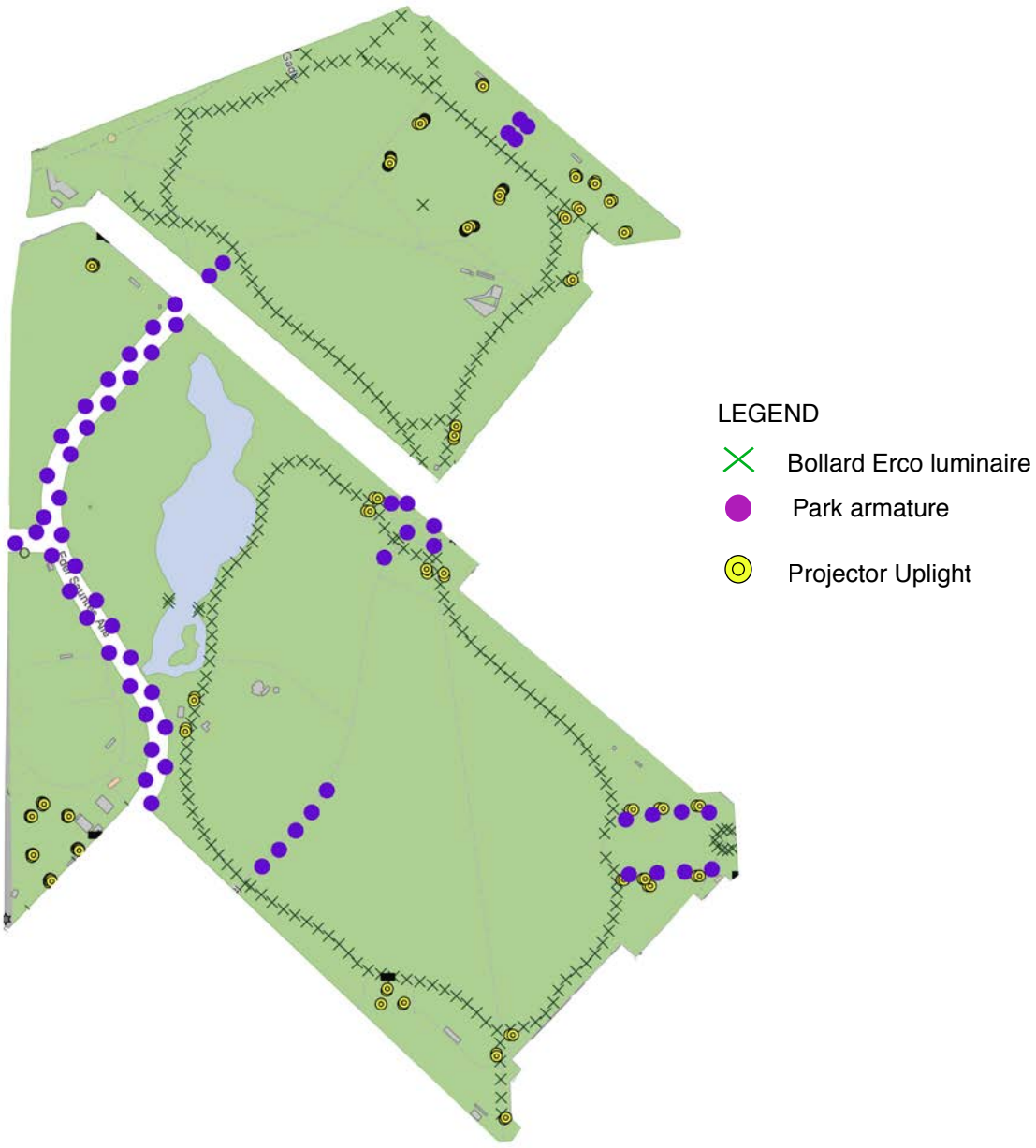


Figure 12. Map of the position of luminaires in Fælledparken

FÆLLEDPARKEN Lux measurements

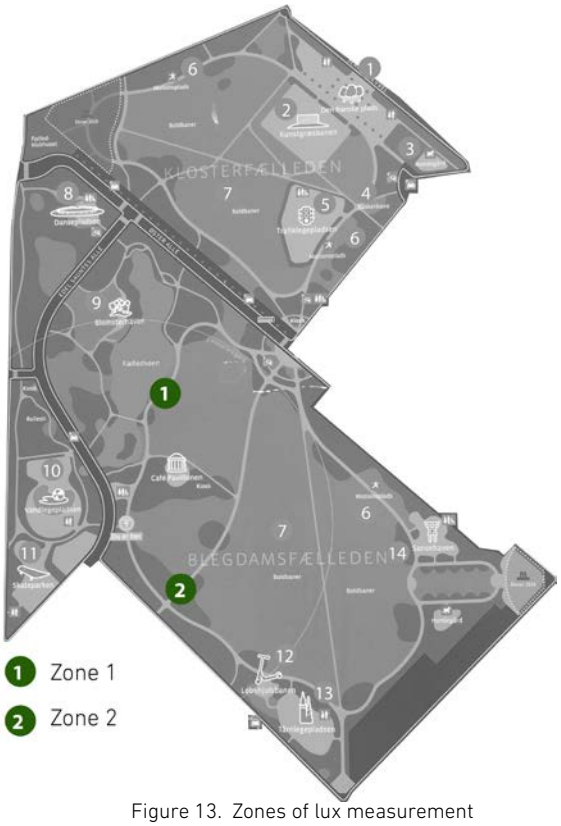


Figure 13. Zones of lux measurement

The map on the left shows the zones in Fælledparken, where illuminance-measurements were taken. The figures 14 and 15 show which type of luminaires is placed in each zone.

The measurements were taken on 22th and 23th of March at 20:00.

1 ZONE 1
ERCO Panorama IP65 floor washing.

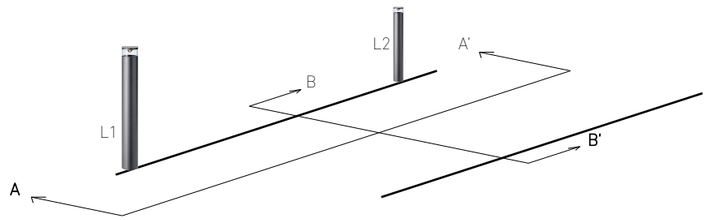
Figrue 14. Photo of the bollard luminaires where measure-metns were taken

2 ZONE 2
PHILIPS Park Armature

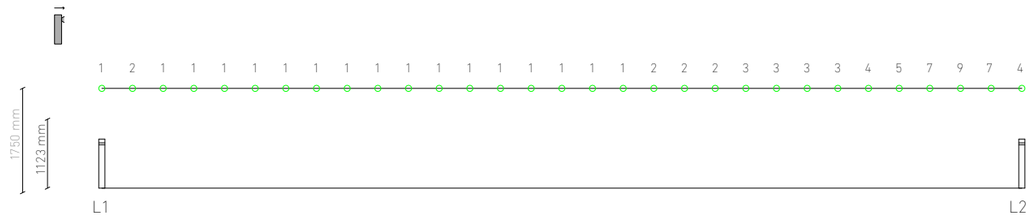
Figrue 15. Photo of one entrance to the park were Philips mast luminaire are located.

VISUALIZATION OF ZONE 1

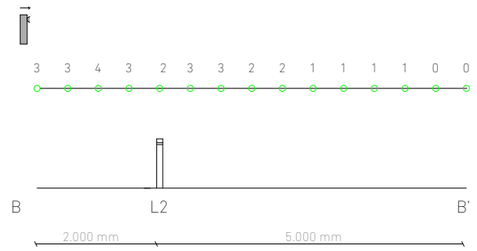
ELEVATIONS A-A' AND B-B'



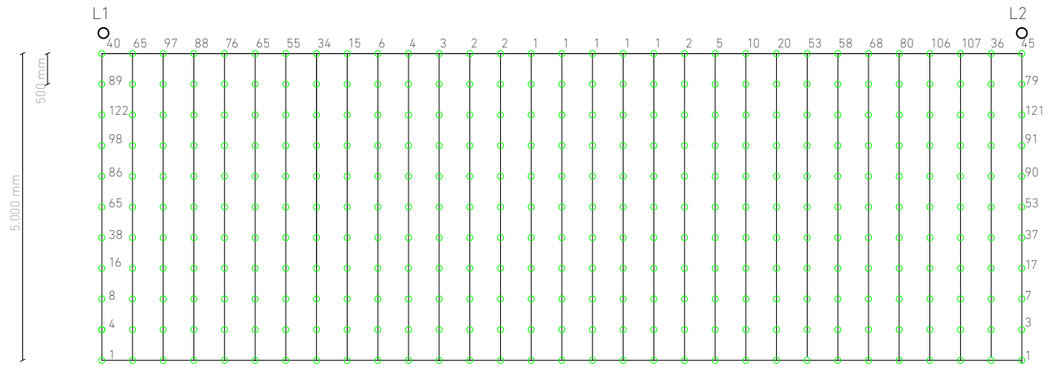
ELEVATION A - Luxmeter pointing L2



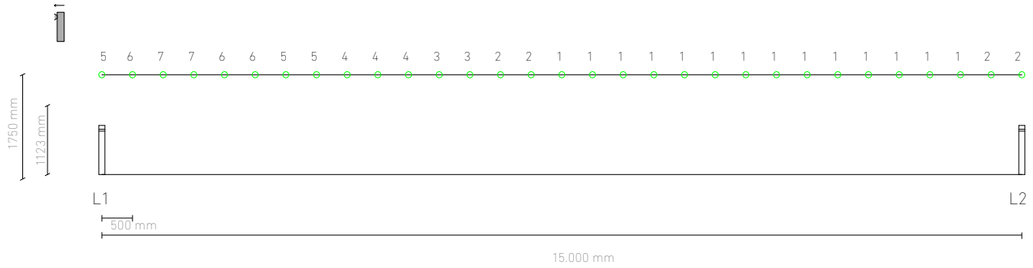
ELEVATION B - Luxmeter direction B-B'



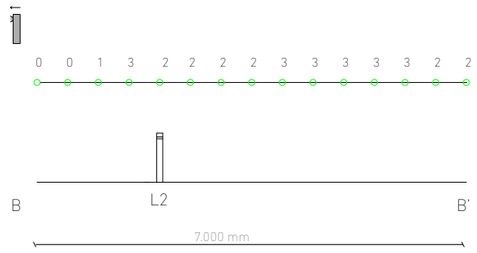
PLAN



ELEVATION A - Luxmeter pointing L1



ELEVATION B - Luxmeter direction B'-B

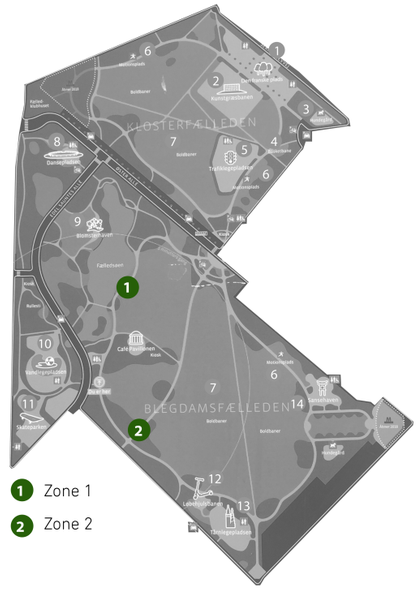


LEGEND

u	Units in Lux
	Luxmeter facing on the arrow direction
	Luxmeter facing on the arrow direction
L1	Luminaire 1
L2	Luminaire 2
	Top view of luminaire
	Scale 1000 mm

FÆLLEDPARKEN Lux measurements

Measurement zones in Fælledparken areal

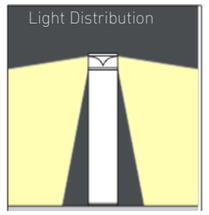


Luminaire Techinical Data

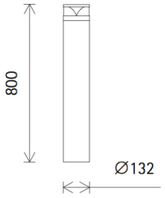
ERCO PANORAMA
IP65 Floor washing

LED source

Light Distribution



Dimentions



Luminous flux of the luminaire	184lm
Connected load	10W
Luminous efficacy	18lm/W
Colour deviation	SDCM<2
Colour rendition index	CRI>90
Lumen maintenance	L80/B10 50000h
LED failure rate	0.1% 50000h
Dimming range	10%-100%
Dimming method	CCR
LMF	E
Energy efficiency class	EEI A+

FÆLLEDPARKEN ANALYSIS Lux measurements

The analyses of lighting measurements starts with the lux values at Zone 1 were the ERCO bollards are located and it continues at Zone 2 with the analyses of the Philips Park.

/ ZONE 1 - ERCO Panorama IP65

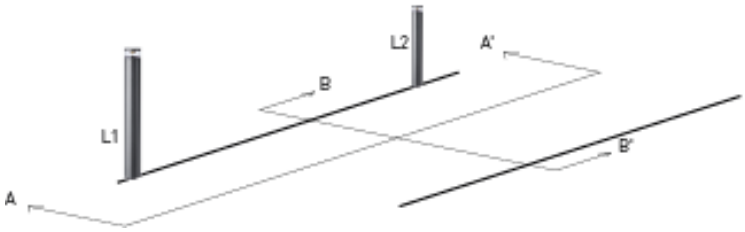


Figure 17. Zone 1 Elevations

The lux measurements at Zone 1 were taken in two different elevations as shown on figure 16. For each elevation lux measurements were taken in two directions, as for example: Elevation AA'- direction A to A' and direction A' to A. The project refers to each one as A-A' and A'-A respectively. The following figure shows, the studied elevations and in the two different levels that measurements were taken. (Level 0: ground floor; Level 1:height of 1,75m)

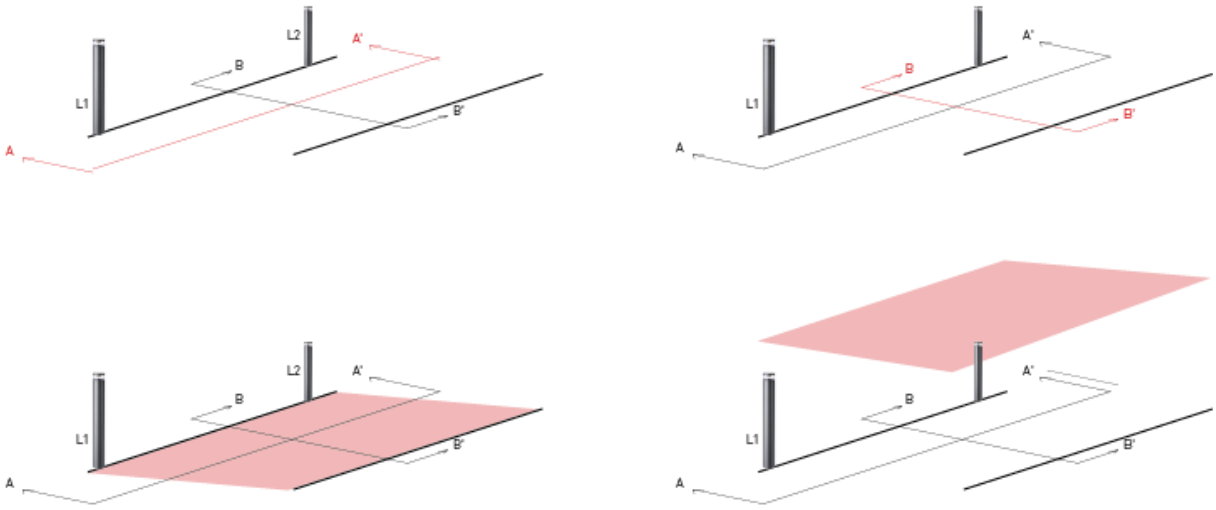


Figure 18. Zone 1 Elevations and height

/ ZONE 1 - ERCO Panorama IP65

Elevation AA'

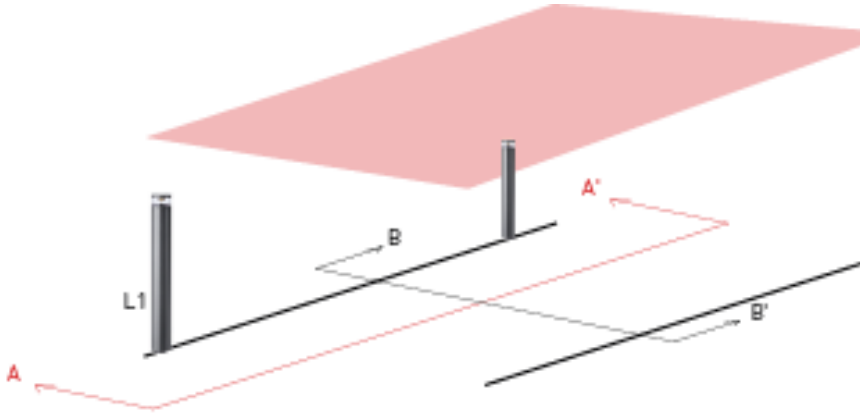
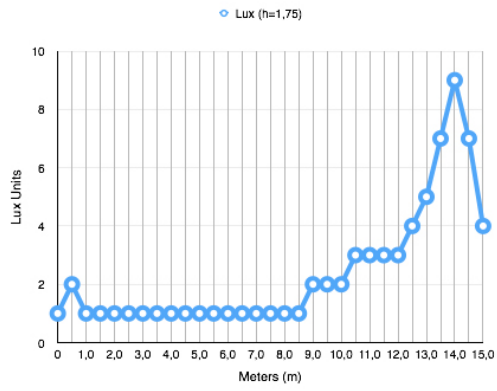
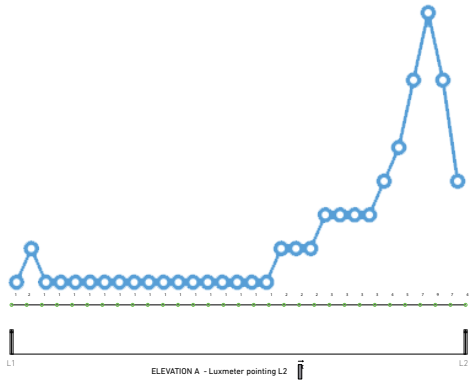
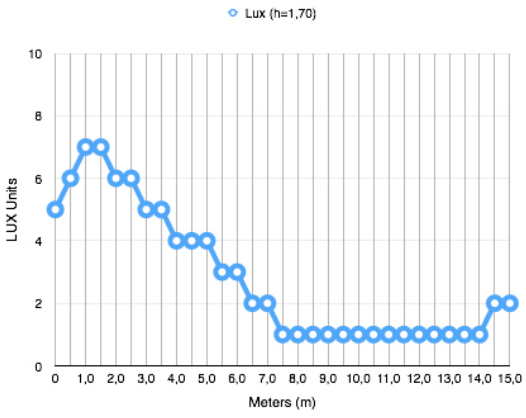
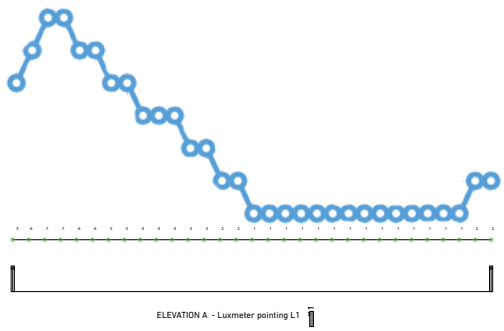


Figure 19. Elevation AA'

The lux measurements on next diagrams correspond to elevation AA' in level 1, height of H=1,75m taken on the vertical axis.

FACE level	Visualization on elevation AA'	
		A-A' Direction
		A'-A Direction

/ ZONE 1 - PHILIPS CITYSWAN BOLLARD

Elevation BB'

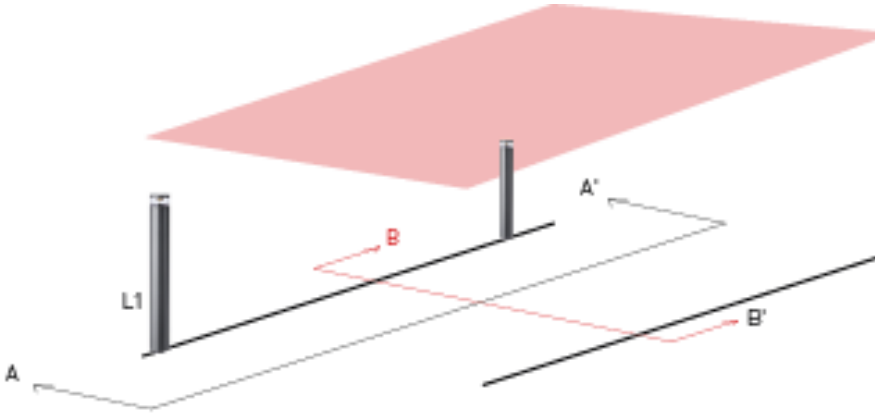
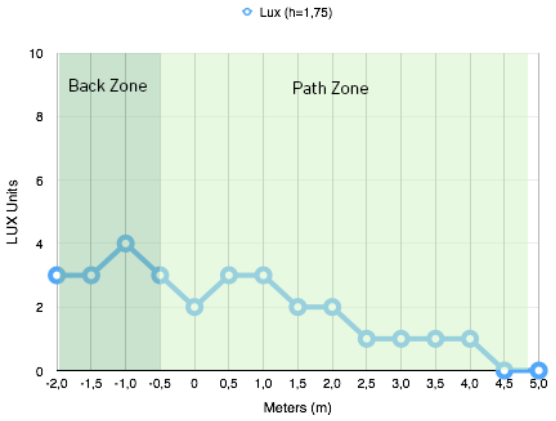
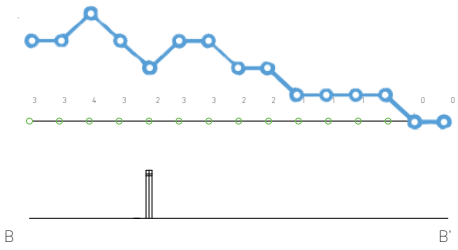
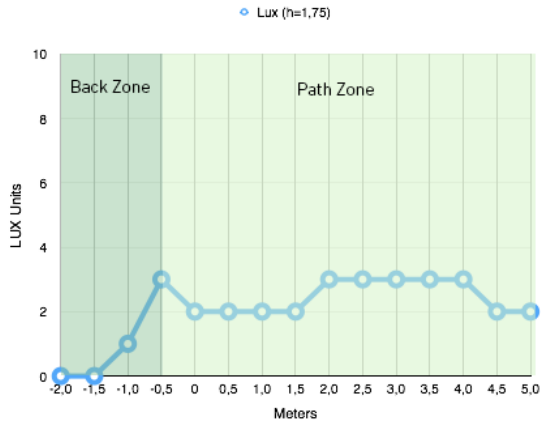
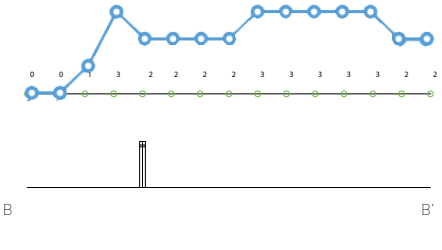


Figure 20. Zone 1 Elevation BB'

The lux measurements on next diagrams are taken at elevation BB' in level 1, that corresponds to a plan on a height of H=1,75m and taken on the vertical axis.

FACE level	Visualization on elevation BB'	
		B-B' Direction
		B'-B Direction

ELEVATION B - Luxmeter on the direction B-B'

ELEVATION B - Luxmeter on the direction B'-B

Elevation AA'

Observing the results, It is evident that highest values are registered when the luxmeter is facing the luminaire, and this happen in both cases A-A' and A'-A. The Lux range goes from 1 to 9 lux for A-A', and 1 to 7 for A'-A. The differences on values can be due bias as: maintenance, spots on the diffuser of the luminaire, the material used to take measurements, etc. In non of the directions has been registered 0 lux in the 15 meters between luminaries. Light distribution is mainly around 2-3lux, on measurements pointing luminaries.

Elevation BB'

Observing the values on elevation BB', results show that it keeps following the same patter as in elevation AA'. Highest values are registered when the luxmeter is faced to the luminaire, and this happen in a distance of 1 meter from the L2 on the back zone of the bollard, were value reach 4lux.

Although, the light strategy of the Copenhagen city hall in parks is to focus the light on the path, avoiding to lit the surrounding to minimize the impact in wildlife, in this case results show that It happens exactly the opposite. The highest measurement is register at 1 meter distance from the luminare on the back side. On the other hand, there is registered zero lux on the B-B' direction, on the path zone at 4-5m from the luminaire. Before that, there is 2 meters where the measurments stay at 1 lux. This fact can be noticed on the diagram curve where between 2m from L2 until 4meters from L2 there is an straight horizontal line at 1Lux. (Diagrams of previous page.)

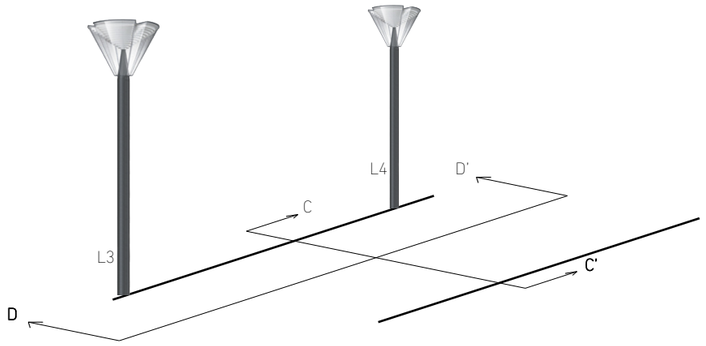
The reason why the lux values on B-B' direction increase after 2 meters of the luminaire it could be due the optics of the luminaire that leads to increase values at the first meters However at the same height and at 4meters ditance of the L2 values start to decrease due less intensity a longer distance. Moreover, there is a possibility that light reflections on the luxmeter's surface have an influence on the values as part of bias.

RELEVANT FOR THE DESIGN:

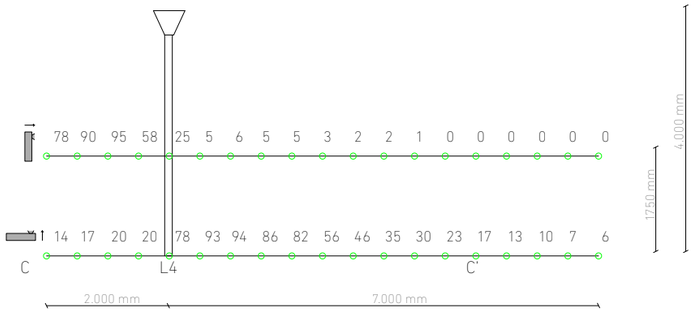
- Find an optics that keeps the highest lux values on the path zone and not on the back zone.
- Right optic for the right design

VISUALIZATION OF ZONE 2

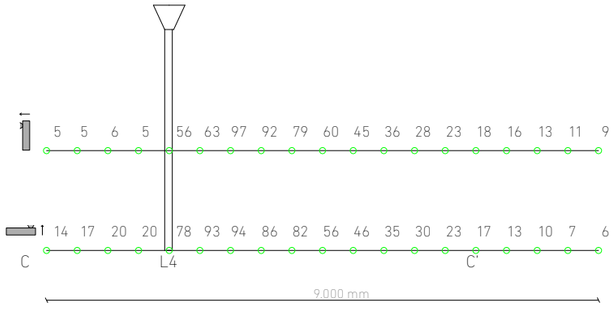
ELEVATIONS C-C' AND D-D'



ELEVATION CC' - Luxmeter direction C-C'



ELEVATION CC'- Luxmeter direction C'-C

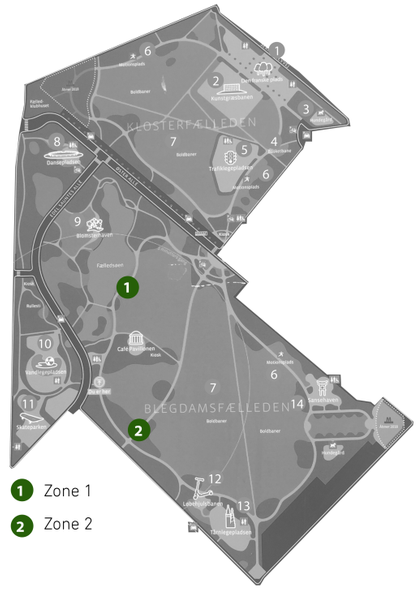


LEGEND

u	Units in Lux
	Luxmeter facing on the arrow direction
	Luxmeter facing on the arrow direction
L1	Luminaire 1
L2	Luminaire 2
	Top view of luminaire
1000 mm	Scale

FÆLLEDPARKEN Lux measurements

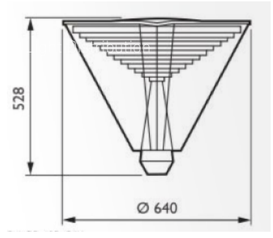
Measurement zones in Fælledparken areal



Luminaire Techinical Data

PHILIPS PARK ARMATURE

Dimentions



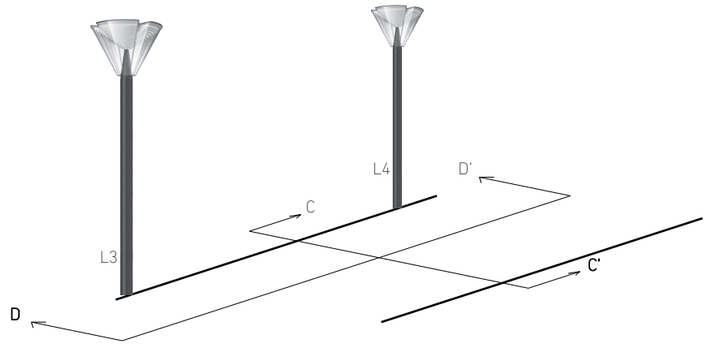
LED source

Color temperature	4000	K
Luminous flux of the luminaire	3614	lm
Power	58	W
Luminous efficacy	62,3	lm/w
Luminous efficiency	9,1	%
Distance between mast	28,0	m
Height of source	4,0	m
Average Lux on ground level	61,0	lx
Average Lux on face level	26,0	lx
Number of luminaire per km	36	luminaires/km
Watts per km	2.088	W/km

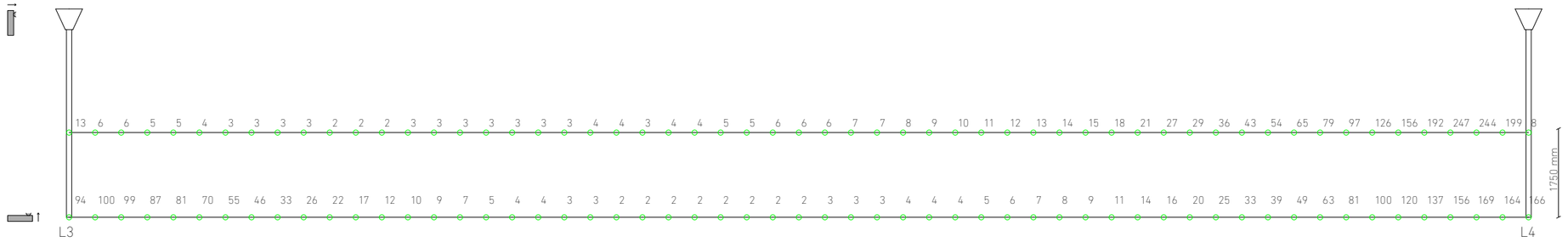
FÆLLEDPARKEN Lux measurements

VISUALIZATION OF ZONE 2

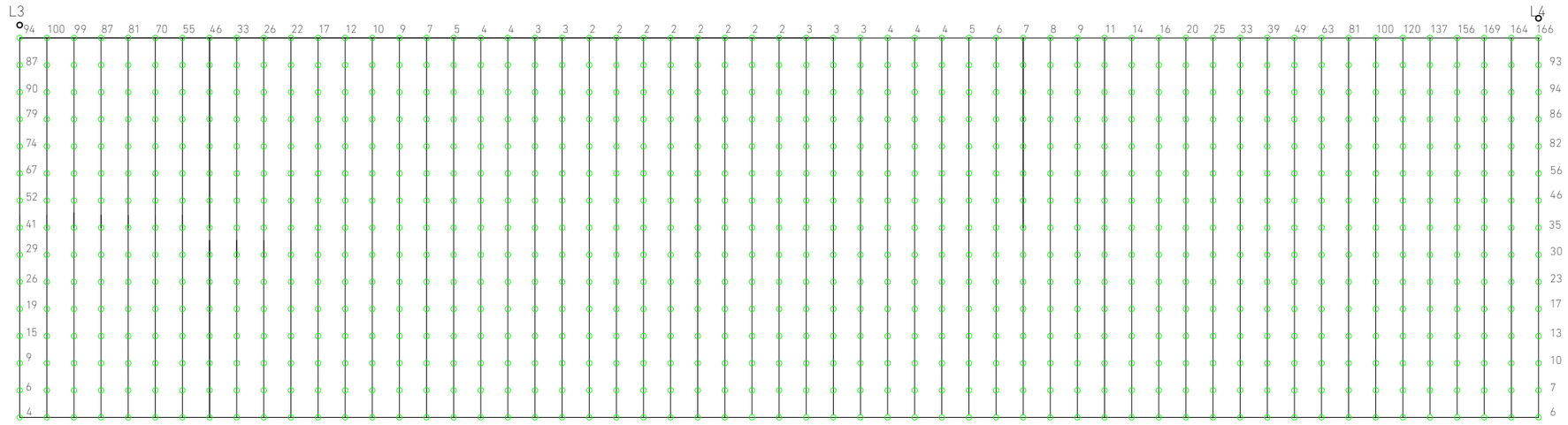
ELEVATIONS C-C' AND D-D'



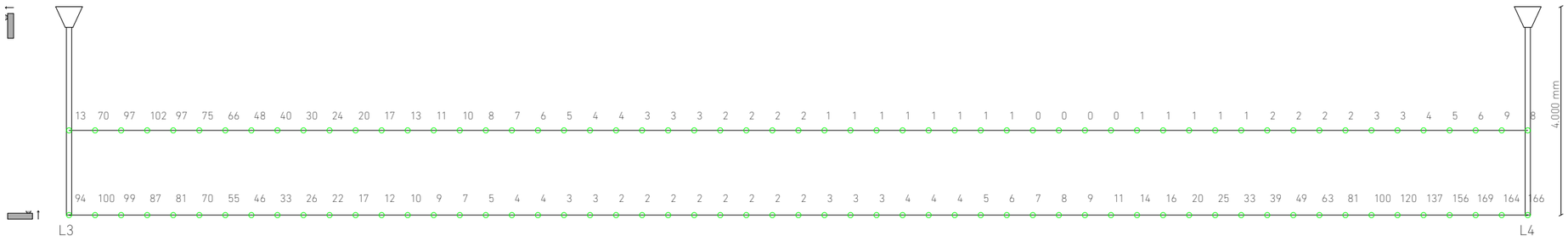
ELEVATION DD' - Luxmeter direction D-D'



PLAN VIEW



ELEVATION DD - Luxmeter direction D'-D



LEGEND

- u Units in Lux
- Luxmeter facing on the arrow direction
- Luxmeter facing on the arrow direction
- L1 Luminaire 1
- L2 Luminaire 2
- Top view of luminaire
- Scale 1000 mm

/ ZONE 2 - PHILIPS PARK BASIC

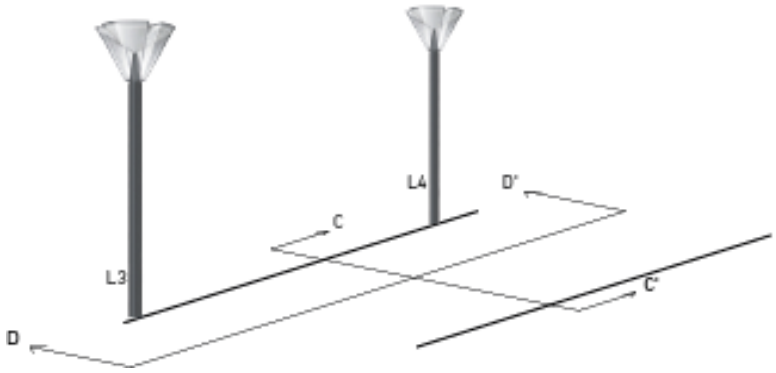


Figure 21. Zone 2 Elevation CC'

The lux measurements at zone two were taken the same procedure as in zone one. Measurements were registered for each elevation in two directions (C-C', C'-C, D-D', and D'-D,) The following figure shows, the studied elevations and in the two different levels that measurements were taken. (Level 0: ground floor; Level 1:height of 1,75m)

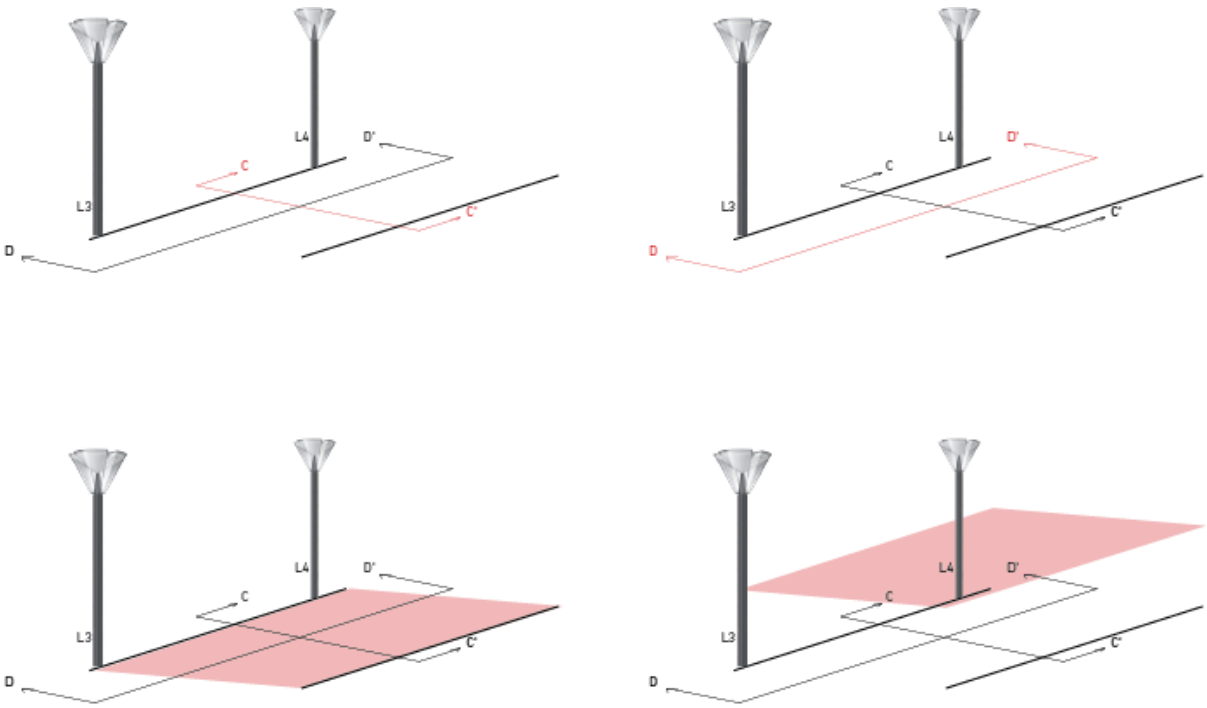


Figure 22. Zone 2 Elevations

/ ZONE 2 - PHILIPS CITYSWAN BASIC

Elevation CC'

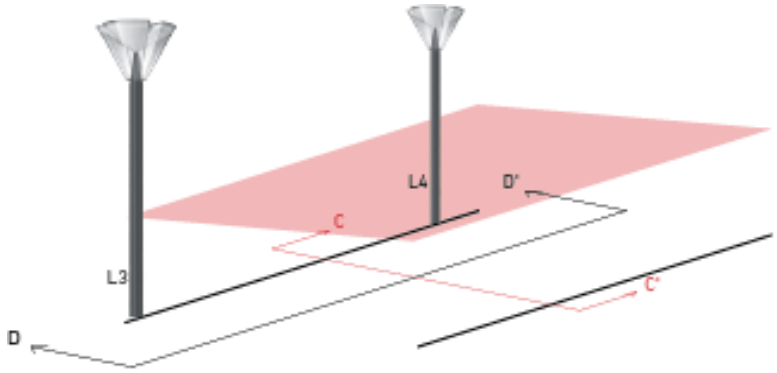
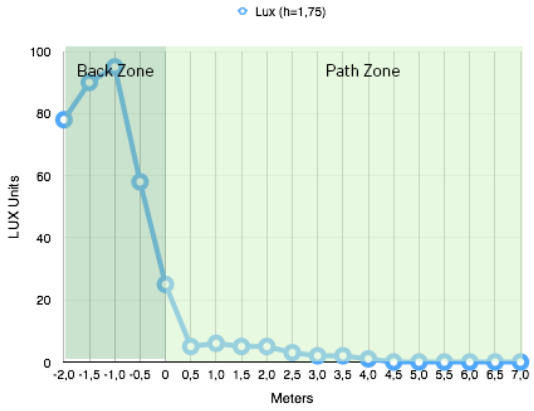
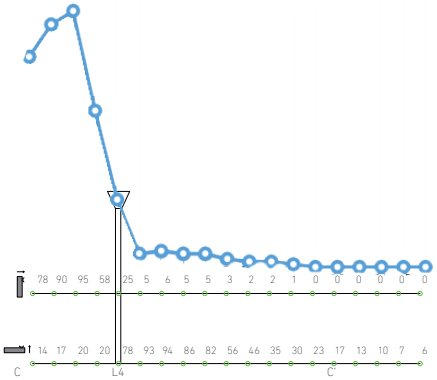
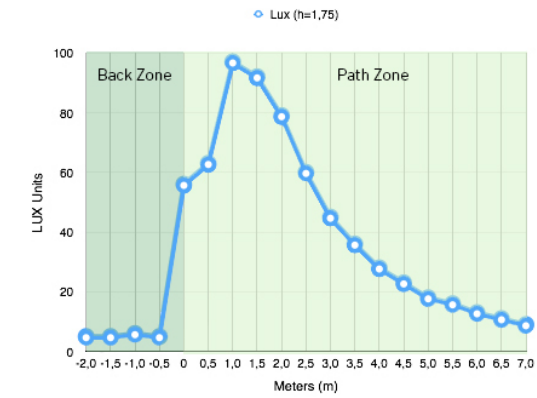
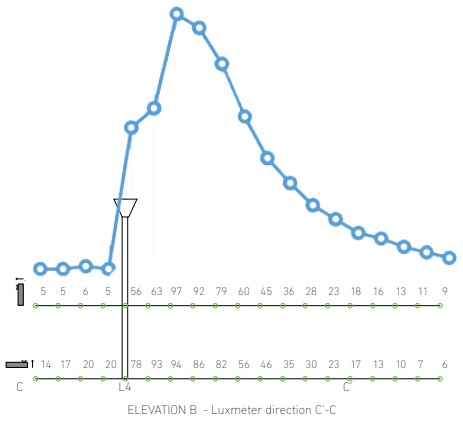


Figure 23. Zone 2 Elevation CC' Level 1

The lux measurements at zone two were taken the same procedure as in zone one. Measurements were registered for each elevation in two directions (C-C', C'-C, D-D', and D'-D,)

FACE level	Visualization on elevation CC'	
		C-C' Direction
		C'-C Direction

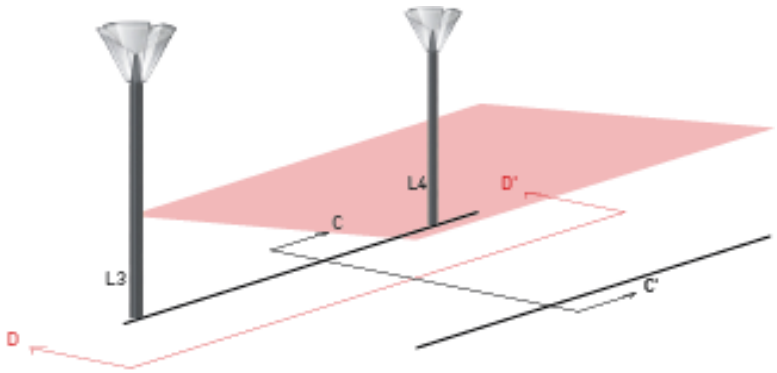
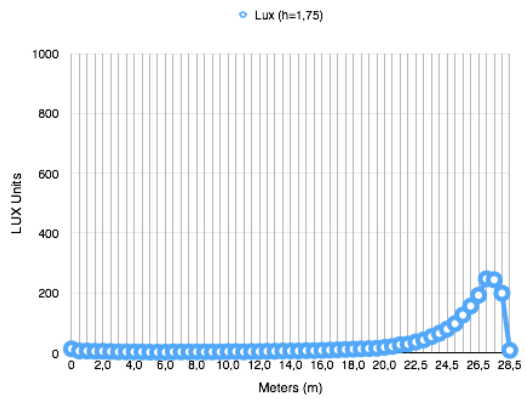
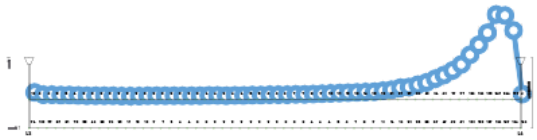
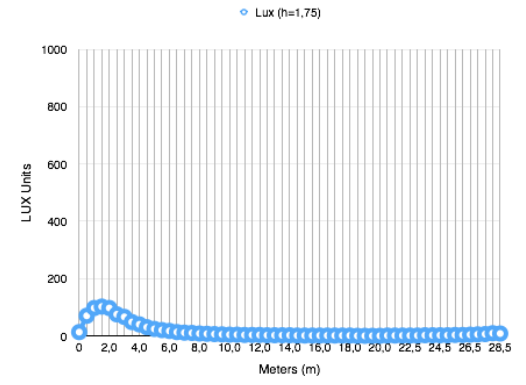
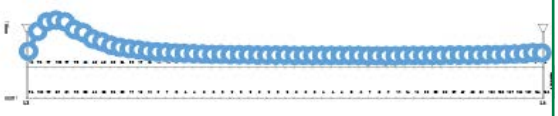


Figure 23. Zone 2 Elevations DD' level 1

The next diagrams show the illuminance measurements from elevation D-D', and D'-D.

Face level	Visualization on elevation DD'	
		D-D' Direction
		D'-D Direction

Elevation CC'

Looking at the diagram on the direction C-C' on the previous pages, It is clear that there is a significant difference between values when the luxmeter is facing the luminare or is in the opposite direction. In this case, the measurements on the back zone are taken when the luminare is facing the L4 and it accentuate the curve on the diagram, in comparison with the values on the path, which are taken when the luminare is facing on the opposite direction. The values range in the direction C-C' goes from 0 to 95 lux, while on the C'-C 5 to 97lux.

Figrue 22. Diagram curve of Lux/meter over the ElevationCC'

On the C'-C direction the lux distribution curve covers the whole width of the path with a value over 9 lux. The values increase gradually until at 1 meter distance, where at that length there is a breakdown. When the luxmeter gets into the back zone, the lux values go down to 5 to stay in an horizontal line for the next 2 meters. However there is an exception at 1 meter distance from the L4, were the lux measurement is 6 units.
Looking at both directions, it is possible to deduct the overall curve of the light distribution of the luminare. FIgure 24 shows both diagrams in one.

The results from this elevation can conclude that the luminaire gives illuminances over 9lux on the pathway at height of 1.75m, meaning that everyone walking on the path during night time, would received at least an amount over 9 lux on the face at that position. However, the optics of the luminare Philips Park brings a symmetric light distribution to the elevation CC ' , which in some cases it can be evaluated as a non desire situation since it is important to concentrate the light over the path and not on the surroundings.

Elevation DD'
On elevation DD' values range is form 0 to 247 lux. Even-tough measurements should be practically around the same value due the same luminaire, It has a significant different between directions DD' or D'D. The highest value is register on L4 with 247lux and for L3 is 102lux. This difference could be to maintenance of the luminaire.

RELEVANT FOR THE DESIGN:
- Define the light distribution desired, then find the right luminaire
- Maintenance has a big influence
- Philips Park use 47W and gives an average of 26lux at a height of 1.75m, based on the lux measurments of the two elevations.

GROUND Level

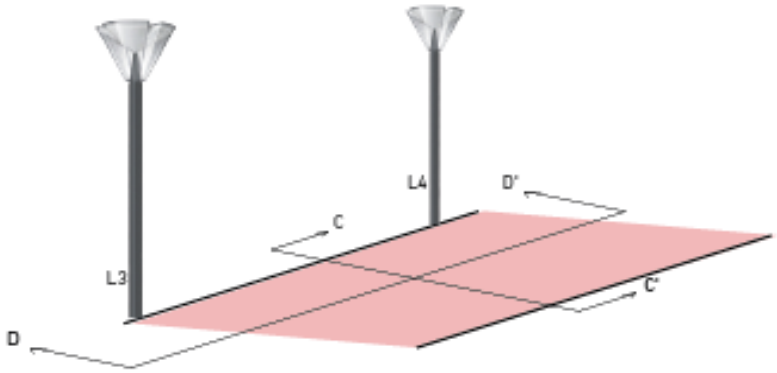
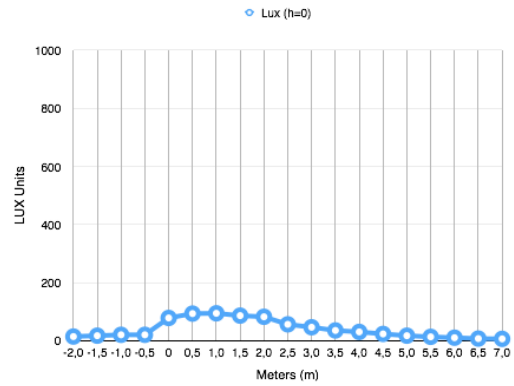
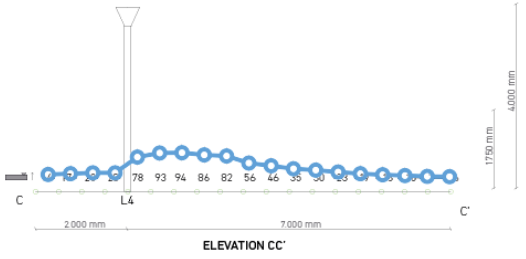
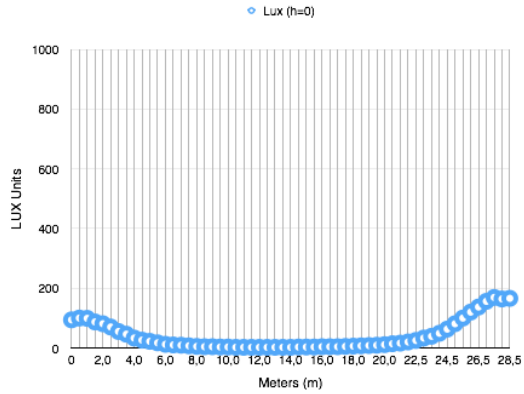
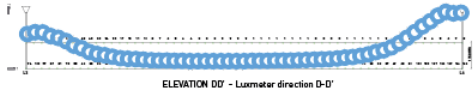


Figure 24. Zone 2 Elevations on Ground level

Next diagrams present the lux measurments taken at Zone 2 on ground level.

GROUND level	Visualization on elevation	
		ELEVATION CC'
		ELEVATION DD'

GROUND Level conclusion

From the graphics Lux/meter on the ground level Its possible to detect that the light distribution of the Luminaire Philips Parks is in a symmetric radial expansion. Lights values are in between 2 and 169lux. There has no been registered zero lux in the 28m between poles.

RELEVANT FOR THE DESIGN:
- Philips park gives a symmetric light distribution on ground level.
- Using 47W the illuminance average of the two axis on ground level is 61 lx, with a minimum of 2lux between poles.

CONCLUSION FÆLLEDPARKEN lighting measurments

The light strategy of Fælledparken consist in using different type of luminaries depending on the required functionality to increase the quality of the park for human activities. Furthermore, lighting the park only in specific zones and pathways, it minimized the impact in wildlife respecting nature and conserving darkness at the rest of the green area.

Moreover, the percussion in nature is minimized by using bollards on the surroundings paths since the light distribution is from a lower height. The comparison of the lux measurments of ERCO bollard and Philips mast luminaire at Zone 1 and Zone 2 respectively, lead to conclude that the higher is placed the source, bigger is the amount of aerial space affected by the light. This evidence prioritize the usage of a bollard system when lighting paths in green areas, which permits to lit a path lessening the impact in wildlife compare to a mast lumianire. However for wider paths It can be more interesting to use high poles.

The ERCO Panorama IP65, use an optic that it distributes the light in 180º to avoid the light on the back zone of the luminaire. The employed optic was made especially for the park. However, on the Philips Website the same luminaire can be found with a 360º of light distribution.

SUM UP RELEVANT FOR THE DESIGN:

- Define the light distribution desired, then find the right luminaire
- Maintenance has a big influence
- Philips Park use 47W and gives an average lux of 26lux at a height of 1.75m
- Philips park gives a symmetric light distribution on ground level.
- Using 47W per luminaire in a distance of 28meters, the average illuminance on ground is 61ls, with a minimum of 2lux.

5.3 ØSTRE ANLÆG

Østre Anlæg is a green area of 12,4 hectares that was part of the old city fortifications located in the inner city of Copenahgen (See Figure.25). There are three lakes in the park that cover 2,4ha of the green area and which used to be part of the moat system. Even though, it is a smaller green area, compare to Amagerfælled or Fælledparken, Østre Anlæg offers to copenhageners a zone in the inner city where they can practice activities as walking, running, picnics, grill, basketball, sunbathing or find there playgrounds.

Figure 25. Green zone reefers to Østre Anlægd location in the Copenhagen areal

The following image (Figure 26) shows the map of the green area and locates the different activities.

Figure 26. Map of Østre Anglæg

ØSTRE ANLÆG photographic report

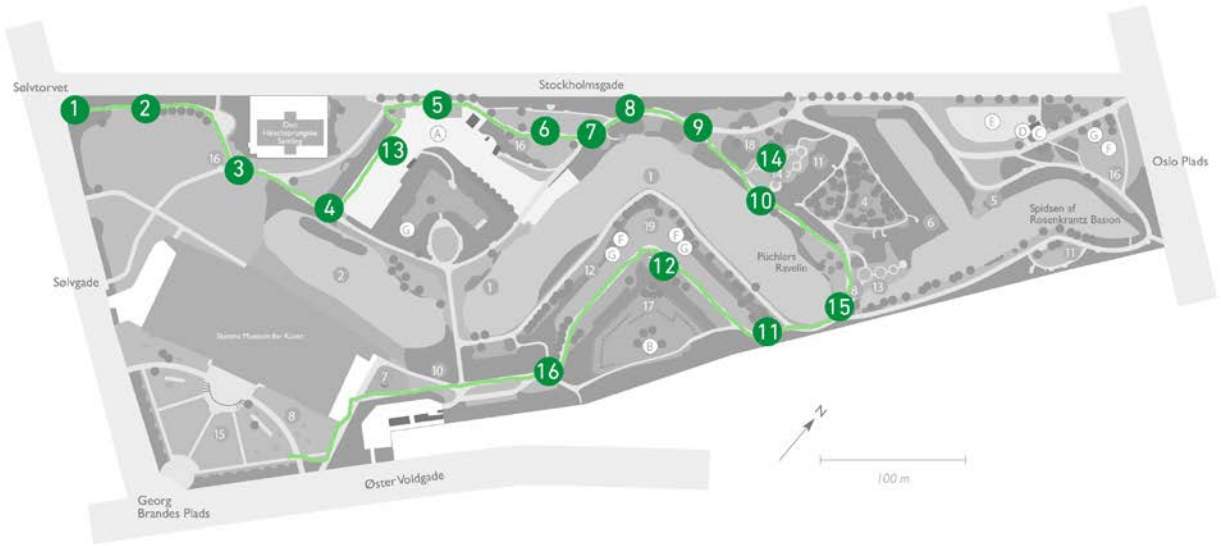


Figure 27. Route of the photographic report at Østre Anlæg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ØSTRE ANLÆG ANALYSES photographic report

EXPERIENCE

Peace and Calm describes the feeling when venturing into Østre Anlæg. The fact that it is a park located in the inner city, seems not to be reflected when walking inside this green area with no high activity. Entering from Sølvtorvet (See figure 27.Map route photographic report) there is located a big open area and the first insight from the area is quite impersonal, lacking of character, the feeling change radically when traveling deeper into the park. The different landscape levels and hills at the North-east of the park create narrow paths with cosy atmospheres, inviting people to chill and relax in nature. (see picture 14, 15 and 16)

There is a big amount of activities that people can practice;walk, run, grill., etc. and playground for kids. The issue comes when there is no daylight and the darkness covers the whole area,bringing an unsafe feeling to users and making the park unusable.

LIGHTING SYSTEM

The first pictures taken for the photographic report date on the 14th of March, unfortunately due the grey and rainy weather of that day, it was decided to repeat the photographic report on the 16th of April.

Exploring Øster Anlæg allowed to observe that there is no lighting system in the area. At night time darkness covers the whole area and it becomes impracticable any type of activity. The area becomes quite and scary.

Although , according to Denmark's Society for Nature Conservation [3] there is a plan to improve the green area, it does not include a lighting system.

RELEVANT FOR THE DESIGN:
- The place must have character to became interesting and inviting people to be there.

- Different landscape levels offer more possibilities to design, and narrow and cosy paths.

ØSTRE ANLÆG Survey

A survey was carried out on the 12th and 14th of march of 2016 at Østre Anlæg. Users of the area were taking a survey of 10 questions with 2 open questions in it.

Find the questionnaire at chapter 9.1 Survey.

ØSTRE ANLÆG ANALYSES Survey

The results show that the highest user percentage is manly people from 34 -44 years old who go there with their child and chill in family. There is also a big percentage of young people which mention that they like to go to the Art Museum of Copenhagen, which is inside the area, and then chill with friends in nature. The high frequency of young people in that area could be due student residents at the streets close to the park.

The highest frequency of the users to visit the park is around two times per week to relax and chill in nature between 12 and 3 pm. All the users agreed on the need of having a lighting system since they do not feel safe at night when the area becomes completely dark.

Regarding to Søndermarken's interactive system the majority of the users did not know about it.

RELEVANT FOR THE DESIGN:

- People prefer narrow paths than open and big areas
- High diversity of plants and trees.
- Lighting system is highly required by users.

ØSTRE ANLÆG technical measurements

Due the absence of lighting in Østre Anlæeg the lighting measurements of this green area are ignored, leading an invalid quantitative research for this area. However, as in the same case of Amagerfælled, the qualitative research will be taken into account for further steps in the design process.

Figure 28. Route armature

Armature Københavnerarmatur, frequent in local roads and mounting in a height of ca. 6 to 8 meters.

Nonetheless, there is placed in this page the lighting used on the surrounding of the park , which is the ordinary wire armature used for street lighting in Copenahgen under the category *Local Roads-residencial buildings* from the *Copenhagen Lighting Masterplan*.

Figure 29. Road armature

5.4 SØNDERMARKEN

Søndermarken is a green area located under Frederiksberg municipality.(Figure 30) This green area gives the opportunity to experience nature in the middle of a metropolitan city. Søndermarken is used for lawns for free film screening, school sports, events, jogging, walk the dog or go for a walk in the hilly wooded landscape.

Figure 30. Green zone reefers to Søndermarken location in the Copenhagen areal

In this area a project called Life & Light turn the green area into a creative modern park where combines culture, nature and movement. The overall aim of the project was to draw attention to the garden and its new opportunities and motivate more people to run, even when it is dark. To achieve this goal , the project consist of fourth layers: a jogging path in the periphery of the park, interactive lighting of the path, marking of all entrances and three venues with exercise facilities.

The following image (Figure 31) shows the map of the green area and located on it the zones for each activity

Figure 31. Map of Søndermarken

ØSTRE ANLÆG photographic report

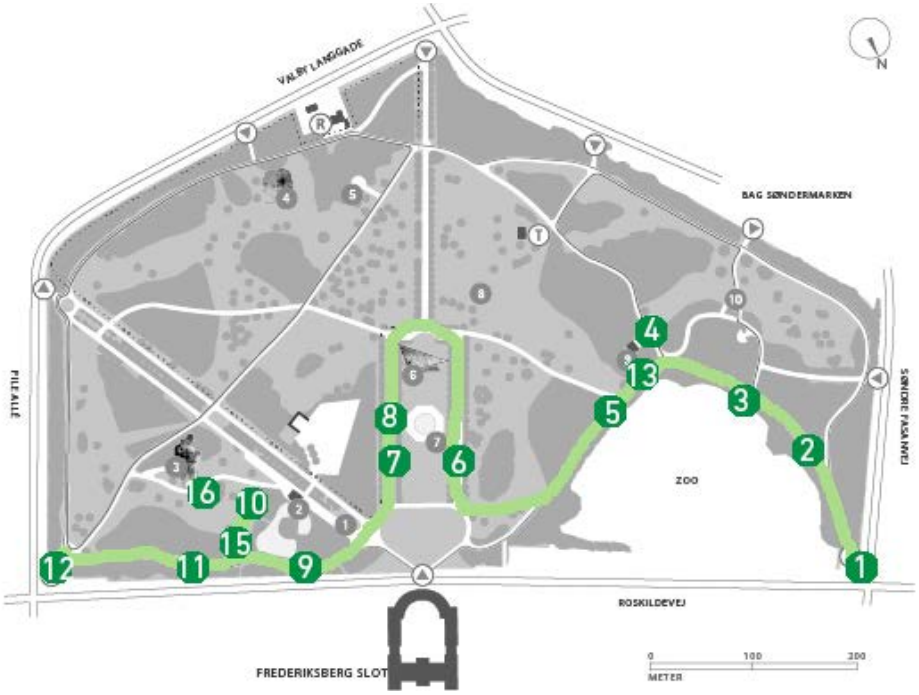

Figure 32. Route of the photographic report at Østre Anlæg


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SØNDERMARKEN ANALYSES photographic report

The photographic report dates on the 18th of March 2016, under a grey and cold weather conditions.

EXPERIENCE

Alive. Active all the time, that is Søndermarken. This park gives energy to its users with different zones and landscapes on the route. The fact that the Zoo is placed next to the park bring a higher number of families with enthusiastic kits to spend time in nature with the possibility to see exotic animals. Furthermore, there is a high number of people going there with their dogs, a big area on top of a hill brings the chance for dogs to play feeling free in nature.

When people go through the park they experience landscape changes all the time through the route. The area turns from big openings into small narrow paths. This transition is smoothly making people feel that they are in adventure where they find surprises on its way, as for example unexpected monument or curiosity that caught their attention.

The park is placed in the inner city and its active all the time, people running walking... and gives them fresh air after a long day in a city. The interactive light in the park also bring runners to improve their running skills while they are in nature.

LIGHTING SYSTEM

The Søndermarken lighting strategy combines interactive bollards around the park's periphery and mast luminaries mainly at the Cisternerne's avenue (see map on technical measurements). The fact that the park is provided with a lighting system cooperates in creating this alive feeling of the atmosphere. When the night falls, people can keep enjoying the area, opening more possibilities for citizens in winter time when there is less hours of daylight.

RELEVANT FOR THE DESIGN:
- Active and inspirational space.
- Animals and nature captivate people.
- Changes on landscape make the area more dynamic and attractive.
- Interactive lighting a tool for design an create an active atmosphere.

SØNDERMARKEN Survey

A survey was carried out on the 18 of March of 2016 at Østre Anlæg. Users of the area were taking a survey of 10 several questions with 2 open questions in it.

See survey questionnaire on chapter 9.1.Survey

SØNDERMARKEN ANALYSES Survey

Carrying a survey was helpful in order to obtain relevant information from users of the area. From the results its possible to observe that the main group using the area is people between 25 and 44 years old with a frequency of either 3-4 times per week. The major activity is running.
The results also show how people mainly use the area during day time and night time thanks to the lighting system. The majority of the users knew about the existence of the interactive lighting, however they think that it is an enjoyable tool but only 15% of them normally use it.

Regarding the open questions about inputs for improving the area and observations, users think that the park offer a lot of opportunities to citizens and they are really happy about it. However some of the users pointed to the lighting system, which has a high contrast of and make difficult in winter time to figure out if there is any ice-block on the ground. Moreover some of them added that the reason why they are not using the interactive system is because it does not fit in their pace speed. Furthermore, users gave inputs about their preferences in a higher variety of nature in the park.

To conclude the survey analyses of Søndermakren seems to be an active park that satisfy pepoles' needs.

RELEVANT FOR THE DESIGN:
- People is happy when they feel free and not limited by daylight.
- Interactive lighting seems an enjoyable tool , but only 15% of people use it.
- Interactive lighting should be more flexible offering an adjustable pace speed to each user.

SØNDERMAKREN technical measurements

This section present the luminaries used in Søndermarken and it specifies in which zones are located. A posteriori lux measurements taken from two different zones in the green area are graphically analysed. Each graphic shows the light distribution that corresponds to each zone and elevation.


Figure 33. Bollard CitySwan

LUMINAIRES

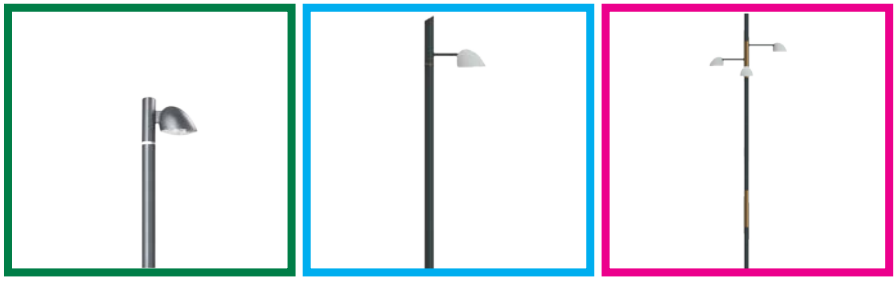
Søndermakren use an interactive lighting system adding an extra layer to the usual image of parks seen until now in Frederiksberg and Copenahgen. Søndermarken uses a Philips CitySwan bollard LED luminaire. (See Figure 33). The bollards illuminate partly the motion path and partly the surrounding areas with a subtle upward and backward light installed behind the top of the bollard (FIgure 34) . On each side of the bollard there is an intelligent Led strips that can be programmed to from five speeds - 5 to 15km/h. Each speed activates a specific colour which stays activated for about three seconds and will guide the runner all over the route.


Figure 34. Bollard CitySwan

At entrances and Cistern avenue there are located mast luminaries which following the same aesthetics as the bollard, they provide light for bigger areas. (Figure 35)


Figure 35. Bollard CitySwan

// Type of luminaries



CitySwan LED Bollard

CitySwan LED Basic

CitySwan LED Bronze
03- Cylindrical mast

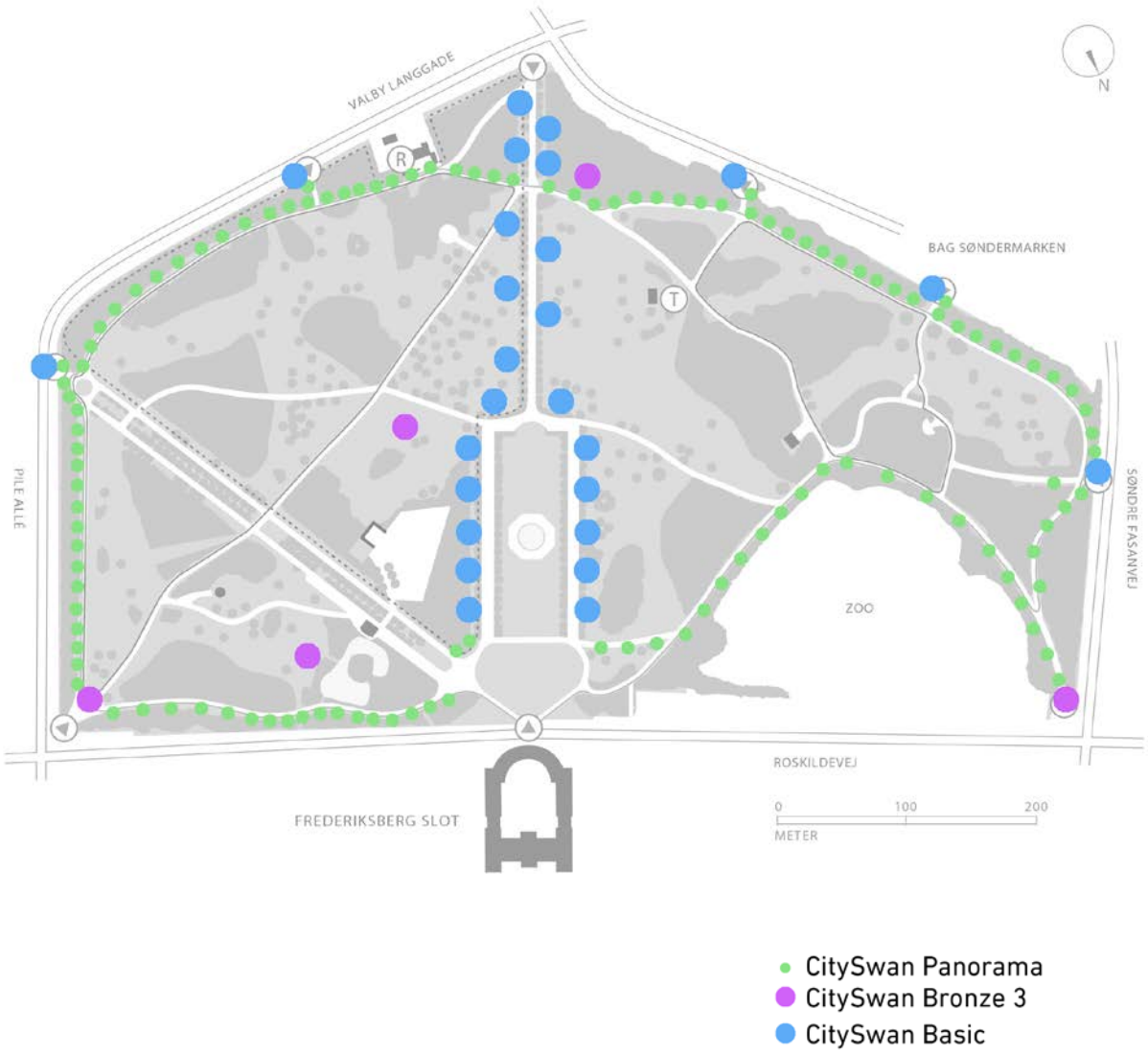


Figure 36. Position of luminaires

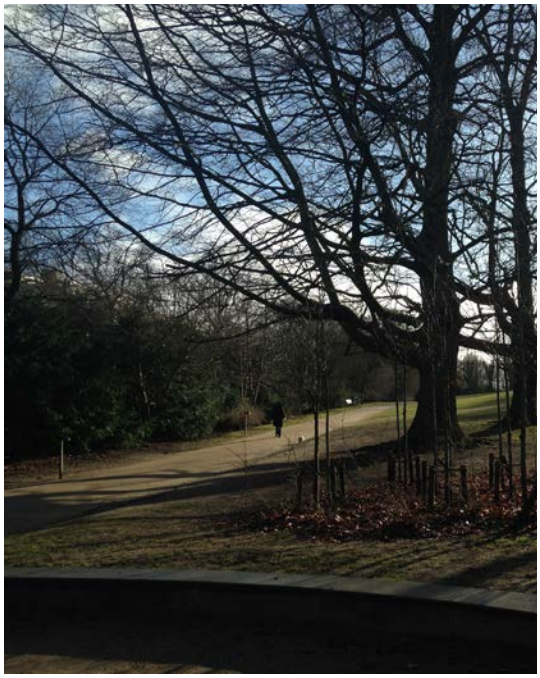
SØNDERMARKEN Lux measurements

The map on the left shows the zones on fælledparken plan, where the lux measurements were taken. The figures 38 and 39 present the type of luminaire that can be found at each zone.

The measurements were taken on 22th and 23th of March at 20:00.

Figure 37. Zones of lux measurement

1 ZONE 1
City Swan Bollard



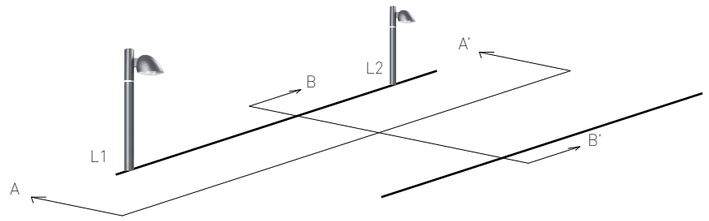
Figrue 38. Photo of the bollard luminaires where measuremetns were taken

2 ZONE 2
City Swan Basic Luminare

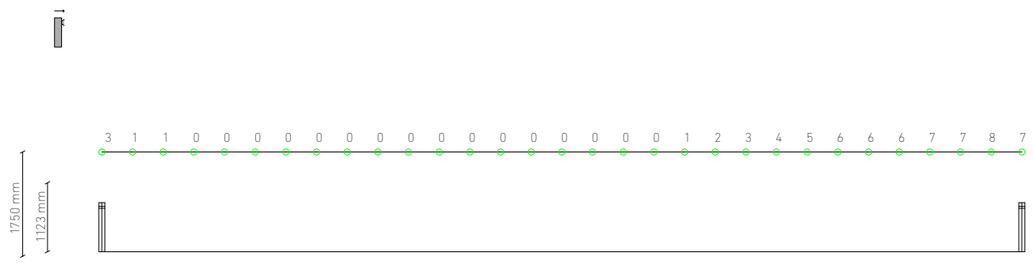
Figrue 39. Photo of one entrance to the park were mast luminaire are located.

VISUALIZATION OF ZONE 1

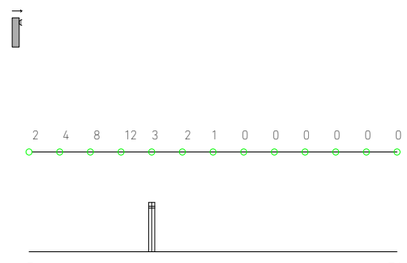
ELEVATIONS A-A' AND B-B'



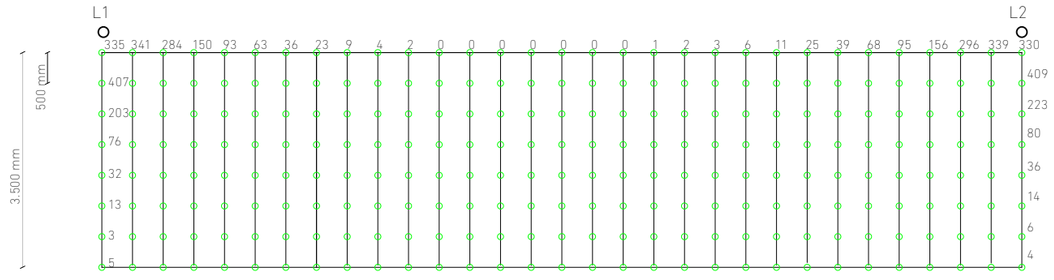
ELEVATION A - Luxmeter pointing L2



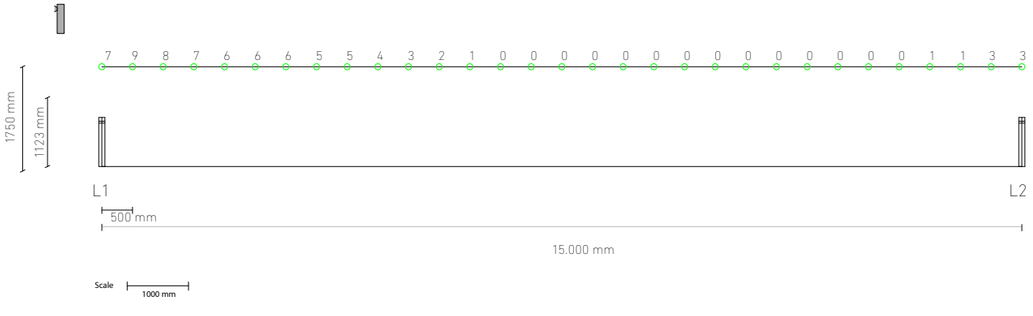
ELEVATION B - Luxmeter on the direction B-B'



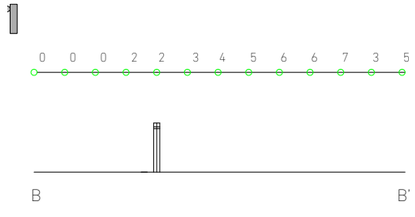
PLAN



ELEVATION A - Luxmeter pointing L1

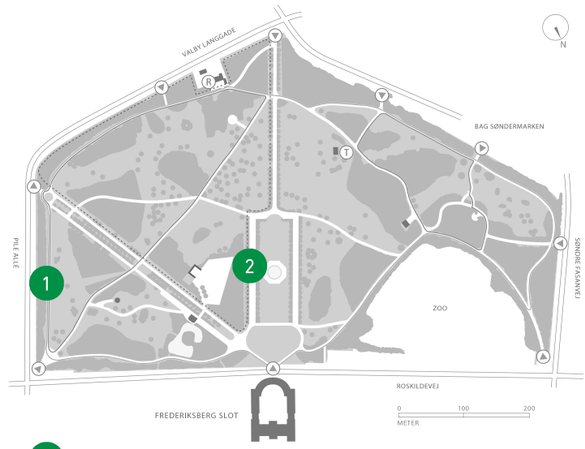


ELEVATION B - Luxmeter pointing of L2



SØNDERMARKEN Lux Mesureaments

Map of Søndermarken areal



1 ZONE 1

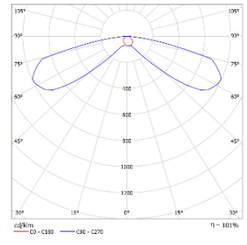
2 ZONE 2

Luminaire Techinical Data

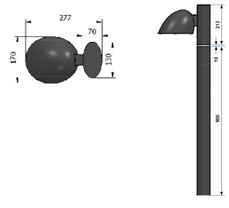
PHILIPS CITIYSWAN
Bollard

LED source

Light distribution



Dimentions



Type	BGP444
Light source	LUXEON
System Power	7 W
Correlated Color Temperature	3.000 K (Warm white)
Luminous flux	380 lm
Color Rendering index	84
Maintenance of lumen output	100,000 hours
Operating temperature range	-20 to +25 °C
Mains voltage	220-240 V / 50-60 Hz

SØNDERMARKEN Analyses Lux measurements

The study of the lighting measurements starts with the analyses of the illuminance at Zone 1 where the Philips CitySwan bollards are located and it continues at Zone 2 with the analyses of the Philips CitySwan Basic Mast.

/ ZONE 1 - PHILIPS CITYSWAN BOLLARD

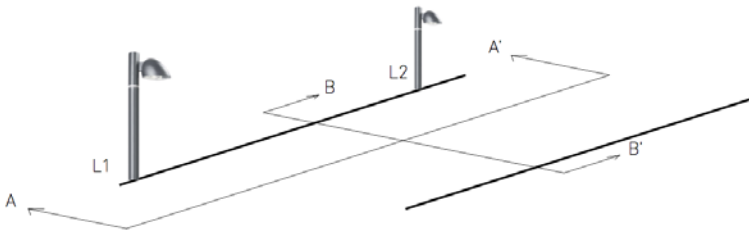


Figure 40. Zones 1

The lux measurements at Zone 1 were taken in two different elevations as shown on figure X. It follows the same procedure used in Fælledparken where at each elevation lux measurements were taken at each axis in both directions, as for example: Elevation AA'- direction A to A' and directon A' to A. The project refers to each one as A-A' and A'-A respectively.

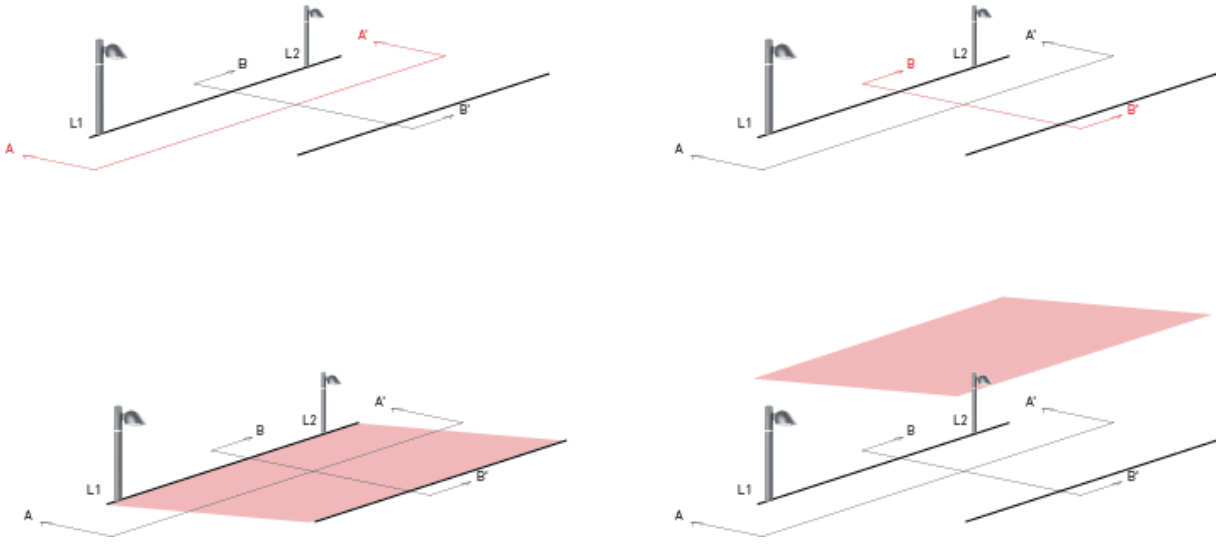


Figure 41. Process

/ ZONE 1 - PHILIPS CITYSWAN BOLLARD

Elevation AA'

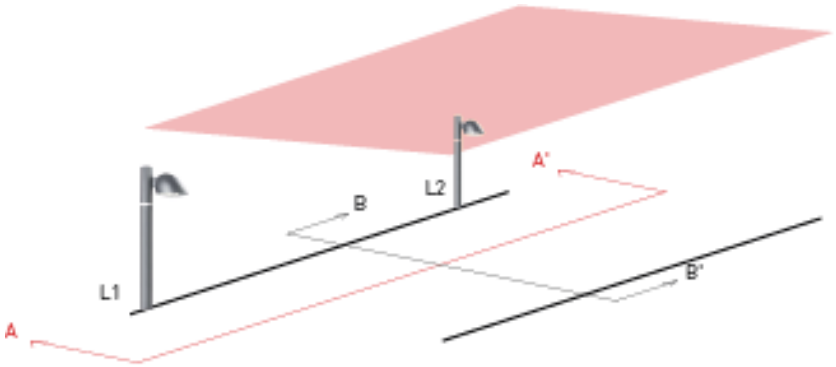
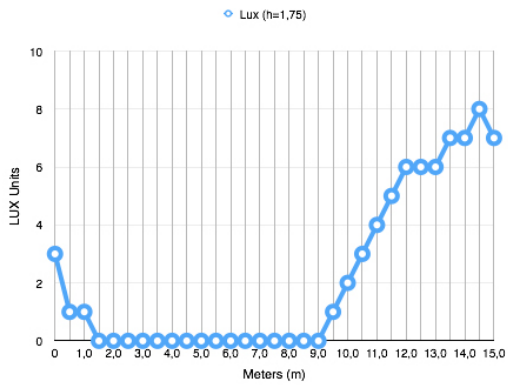
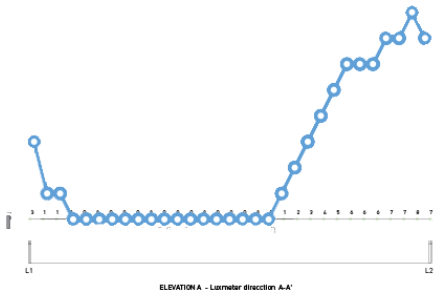
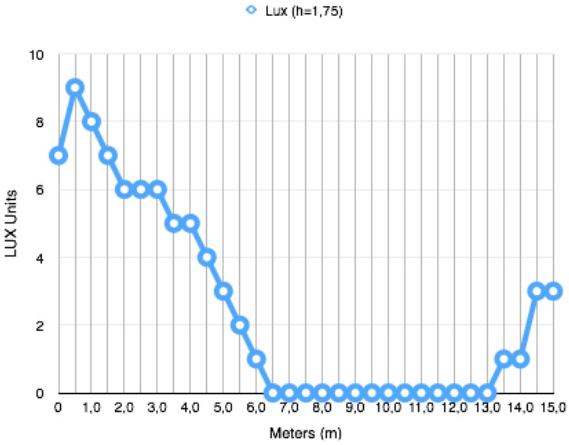
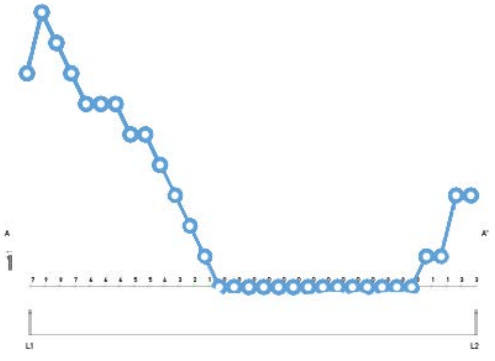


Figure 42. Elevation AA' level 1

The lux measurements on next diagrams correspond to a vertical plan on a height of H=1,75m. (Figure 42)

FACE level	Visualization on elevation AA'	
		A-A' Direction
		A'-A Direction

/ ZONE 1 - PHILIPS CITYSWAN BOLLARD

Elevation BB'

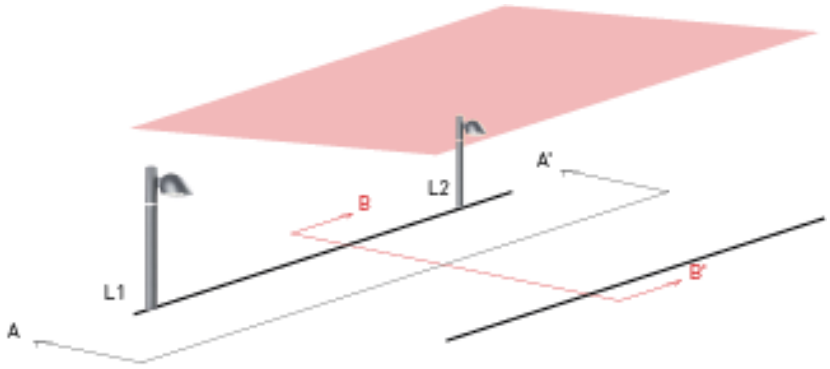
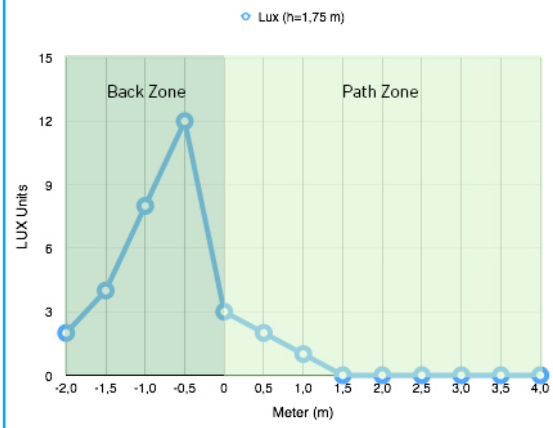
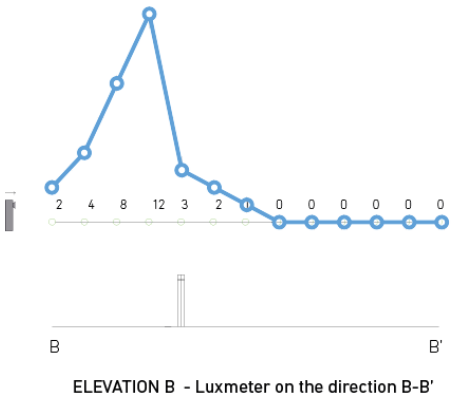
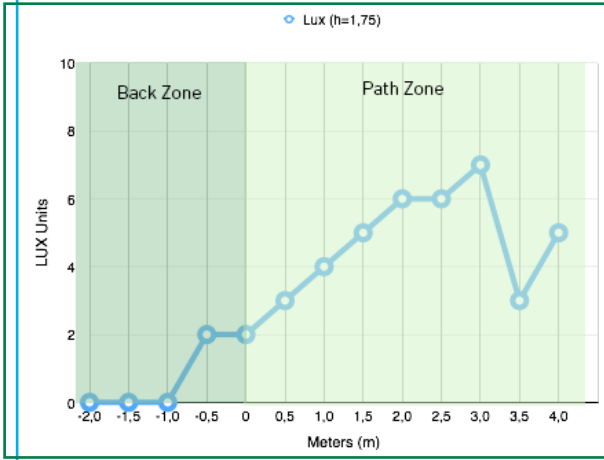
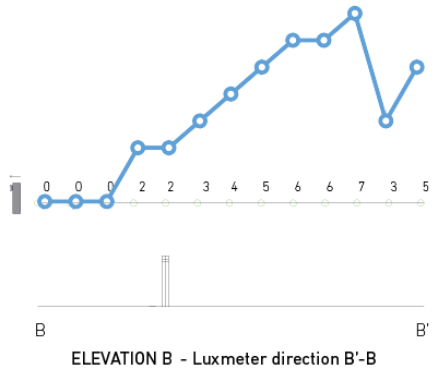


Figure 43. Elevation BB' level 1

The lux measurements on next diagrams correspond to the vertical axis on a height of H=1,75m (Figure 43).

FACE level	Visualization on elevation BB'	
		B-B' Direction
		B'-B Direction

Elevation AA'

As in previous cases , there is registered an small variation between lux ranges in the different directions, even thought it should be exactly the same , since it is the same product. The differences on values can be due several circumstances, maintenance, spots on the diffuser of the luminaire or other bias. In both directions it has been registered 0 lux between this two luminaries which far 15meter from each-other.

Elevation BB'

Looking at the graphic results on the previous page, there is a drastic difference between the measurements in the Back Zone and the Path Zone. This outcome does not seem in accordance to the Copenhagen master plan, which specifies that the lighting in green areas must be respectful to wildlife and avoid to lit path's surroundings. However, the result is according to the design of the luminary which has an extra light source on the back side pointing up-words. (See figure 44)

Figure 44. Bollard CitySwan, back lighting.

This lighting effect increase the vision field when walking by night through the green area. Additionally to the enough light on the path, people receive extra information of the surrounding. Although this lighting can increase the safety feeling of people, it has a higher impact in wildlife, due back-lighting.

On the direction B'B there is a breakdown to 3lux at 3 meters from L2, just after the highest pick. This it could be due some unexpected object covering part of the light on the surface of the luxmeter or that the luxmeter was placed wrong, since the values increase again up to 5lux.

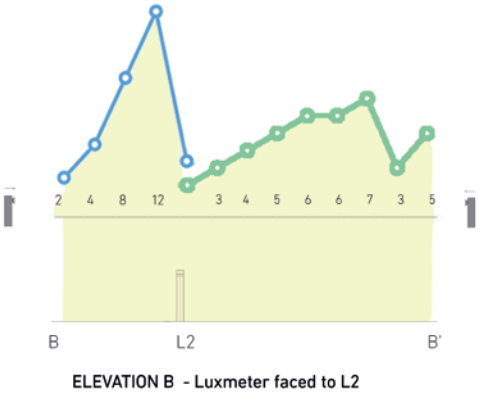


Figure 45. Curves in the same graphic

Once the graphics lux/meter has been observed individually, it is interesting to see how is the overall curve when they are placed on top of each other. In this case due the back-lighting the result does not gives an smooth curve between the transition of the two zones. (Figure 45)

The results from both elevations in Søndermarken, show that the average lux on a vertical axis at a height of 1.75m is 4,3lux.

RELEVANT FOR THE DESIGN:

- CitySwan Design gives high values on the back side of the bollard, but only on the 1'5m from the luminaire, giving information of the surroundings to users.
- CitySwan Bollard with 7W gives an average lux of 4,3lux at a height of 1.75m

GROUND Level

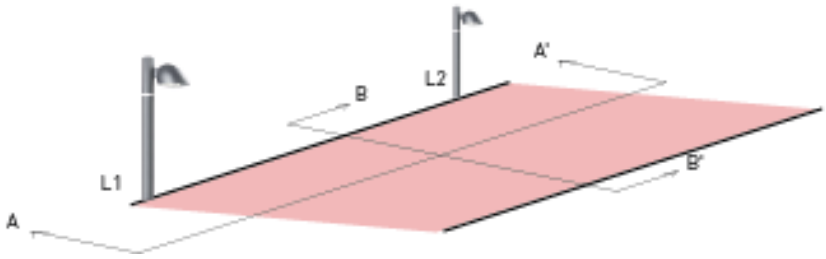
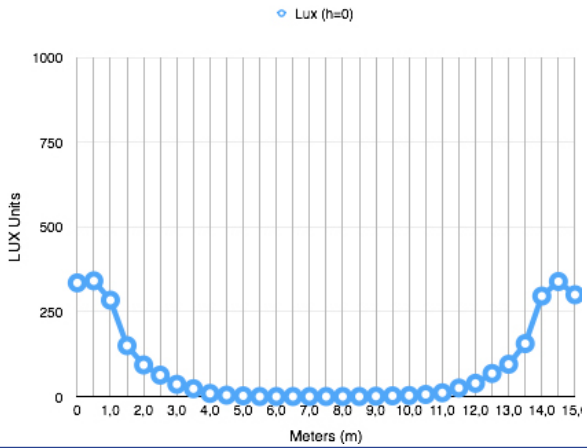
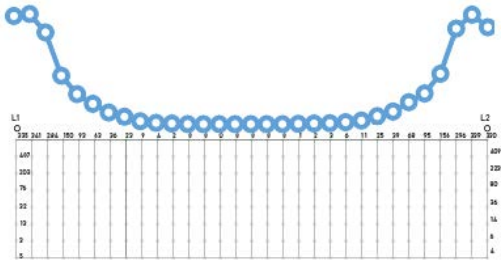
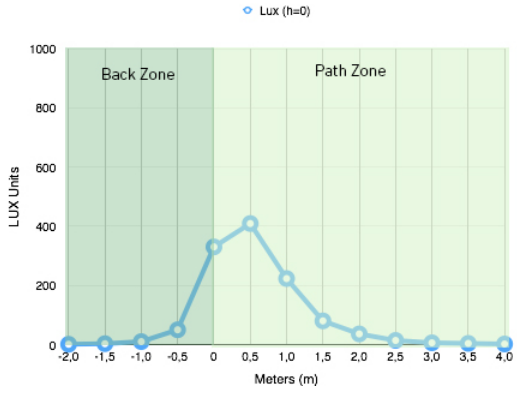
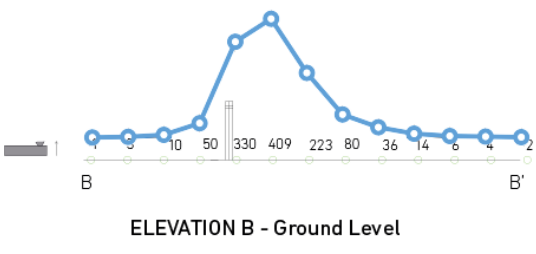


Figure 46. Ground level measurments

The following diagrams correspond to illuminances on the gorund level.

GROUND level	Visualization on elevation	
		ELEVATION AA'
		ELEVATION BB'

GROUND Level conclusion

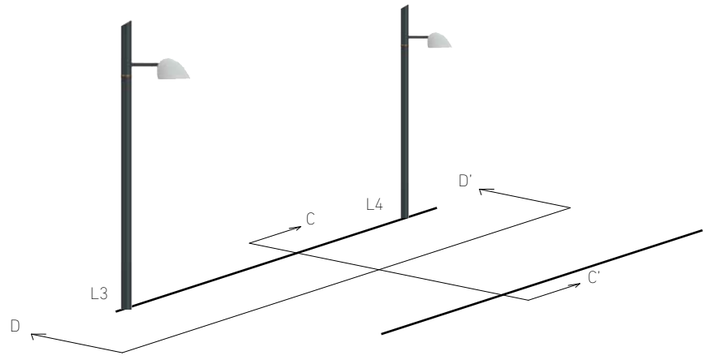
From the graphics Lux/meter on the ground level Its possible to observe that the light distribution of the Luminaire CitySwan has an asymmetric light distribution on the ground. Lights values goes from 4 lx to 409 lux over the pathway, with an average of 95,6lx, when considering the values from both elevations.

In the whole distance of 15m between poles, the light distribution on the path it presents high differences in lux values. When at one meter from the pole we can find values up to 409, there is areas where values go down to 0 lux, as for example during the 3 meters starting at 5m from L1.

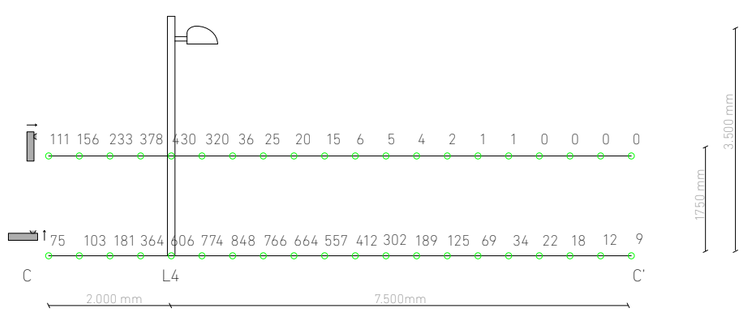
RELEVANT FOR THE DESIGN:
- CitySwan Bollard gives an asymmetric light distribution on ground level.
- CitySwan use 7W per luminaire and gives an average of 95,6lux on ground.
- If bollards are placed in a distance of 15m, then there is registered 3meterso in between where lux are zero.

VISUALIZATION OF ZONE 2

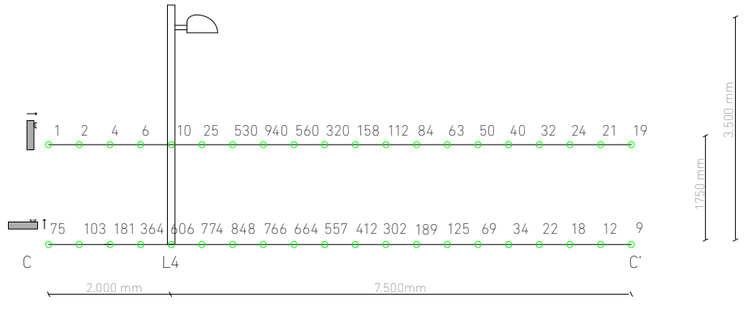
ELEVATIONS C-C' AND D-D'



ELEVATION C - Luxmeter direcction C-C'



ELEVATION C - Luxmeter direccrtion C'-C

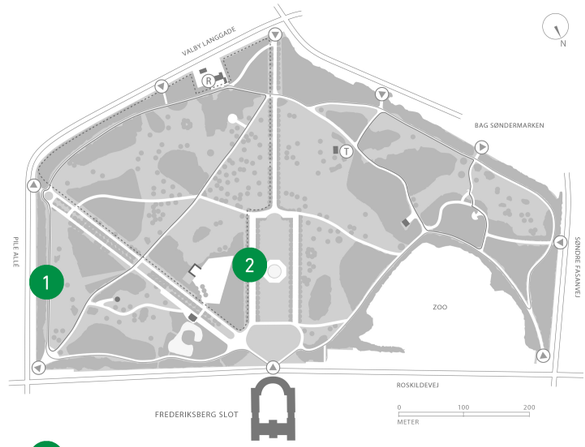


LEGEND

- u — Units in Lux
- Luxmeter facing on the arrow direction
- Luxmeter facing on the arrow direction
- L1 — Luminaire 1
- L2 — Luminaire 2
- Top view of luminaire
- Scale (1000 mm)

SØNDERMARKEN Lux Mesureaments

Map of Søndermarken areal



1 ZONE 1

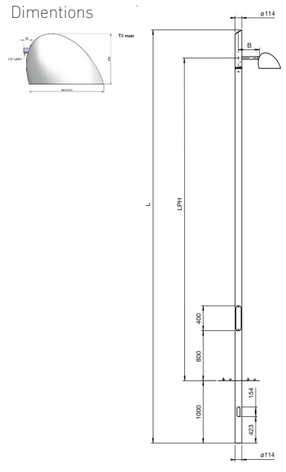
2 ZONE 2

Luminaire Techinical Data

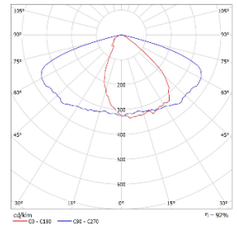
PHILIPS CITIYSWAN BASIC

LED source

Dimentions



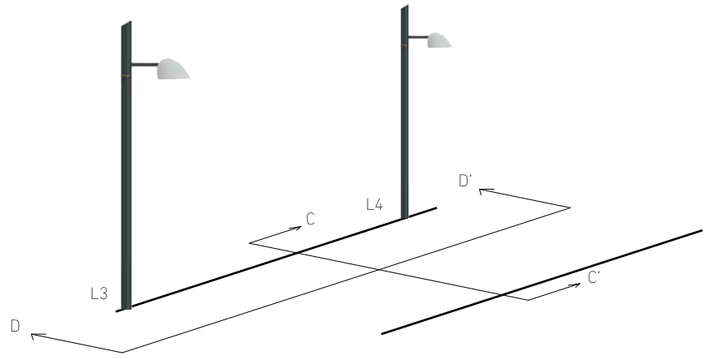
Light distribution



Type	BRS439
Lamp family	GRN24 [LED greenline 2400lm]
Power Consumption	60 W
Correlated Color Temperature	3.000 K (Warm white)
Luminous flux	2400 lm
Color Rendering index	84
Optics	O-DC - Distribution Comfort
Ingress protection code	IP65 [Dust penetration protected, jet-proof]
Mains voltage	220-240 V / 50-60 Hz

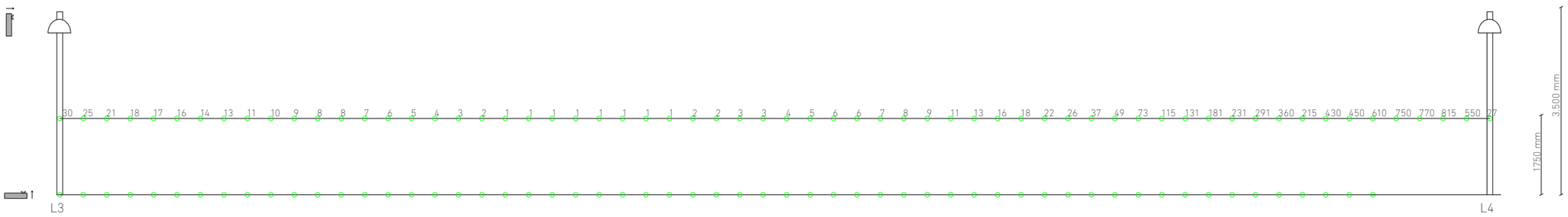
VISUALIZATION OF ZONE 2

ELEVATIONS C-C' AND D-D'

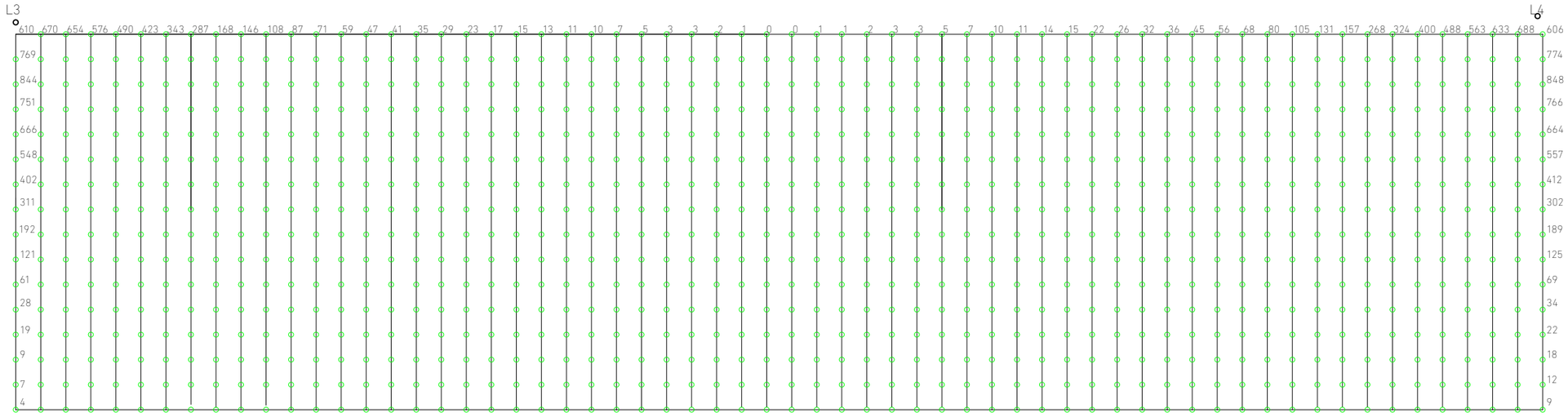


SØNDERMARKEN Lux Mesureaments

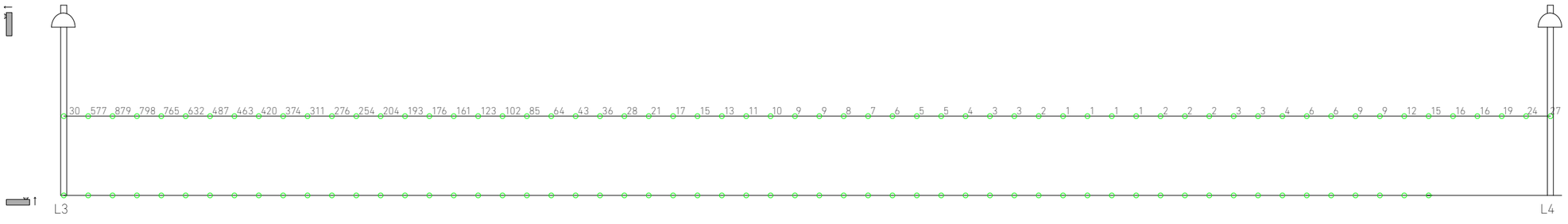
ELEVATION DD' - Luxmeter direction D-D'



PLAN VIEW



ELEVATION DD - Luxmeter direction D'-D



LEGEND

- u Units in Lux
- Luxmeter facing on the arrow direction
- Luxmeter facing on the arrow direction
- L1 Luminaire 1
- L2 Luminaire 2
- Top view of luminaire
- Scale

1000 mm

/ ZONE 2 - PHILIPS CITYSWAN BASIC

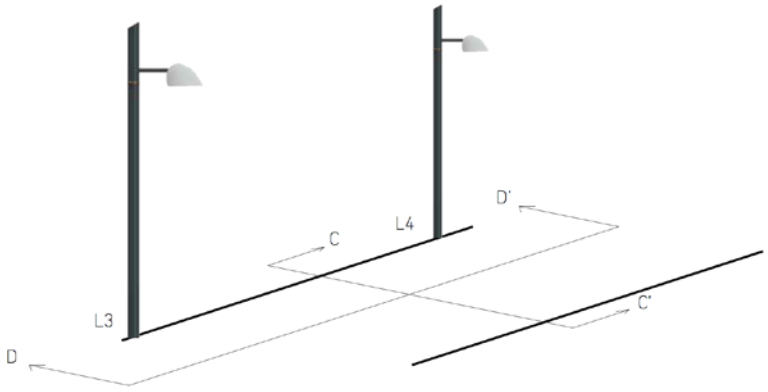


Figure 47. Zone 2

The lux measurements at zone two were taken the same procedure as in zone one. Measurements were registered for each elevation in two directions (C-C', C'-C, D-D', and D'-D,)

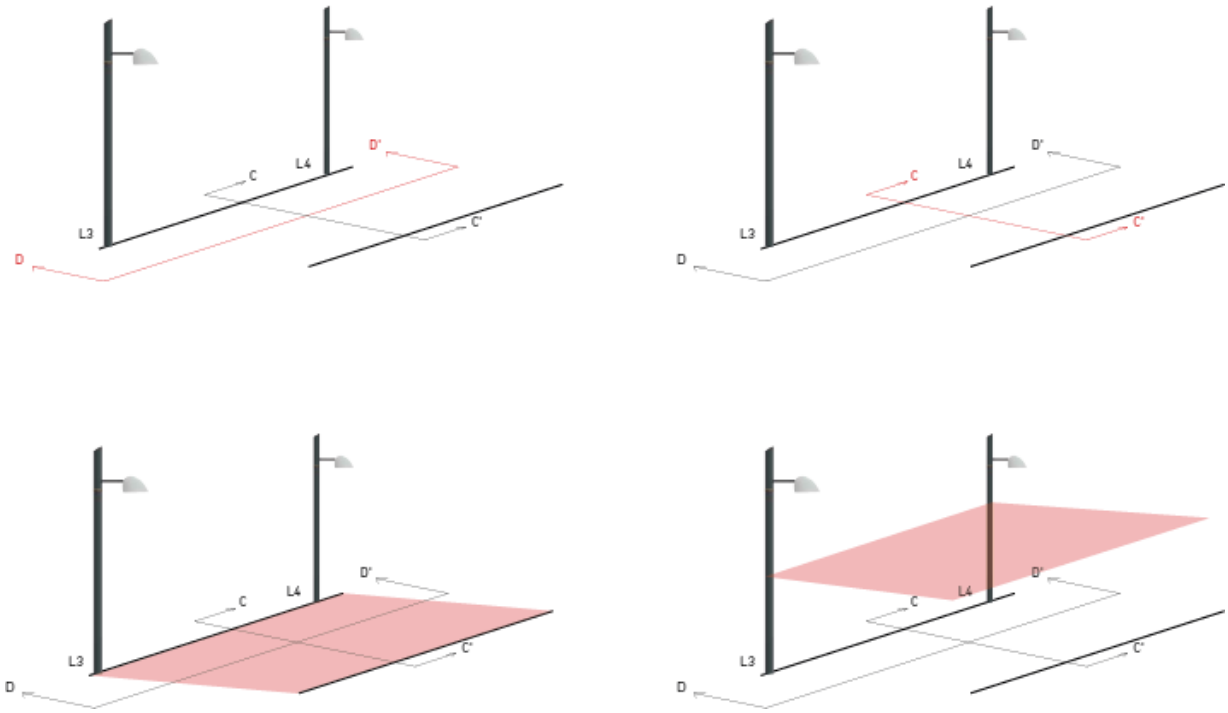


Figure 48. Procedure

/ ZONE 2 - PHILIPS CITYSWAN BASIC

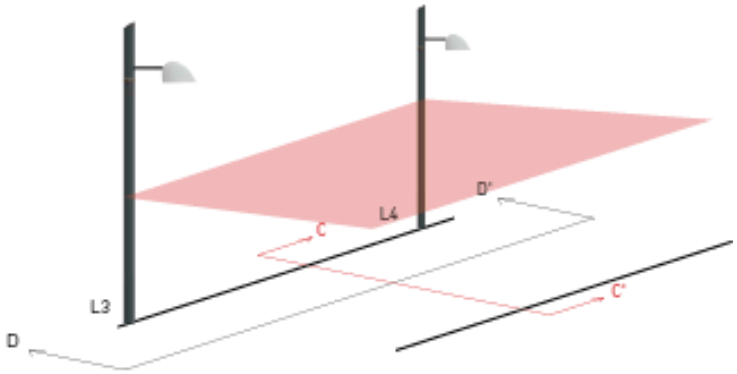
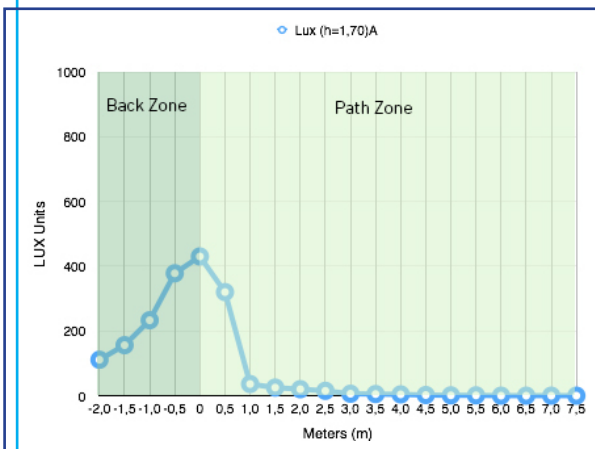
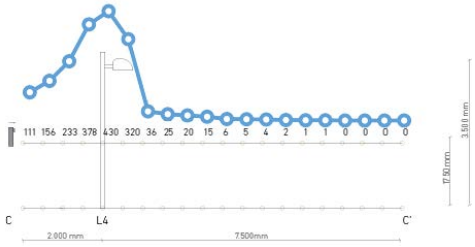
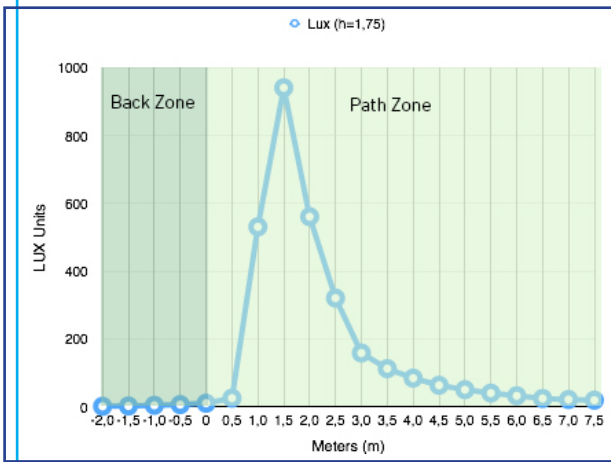
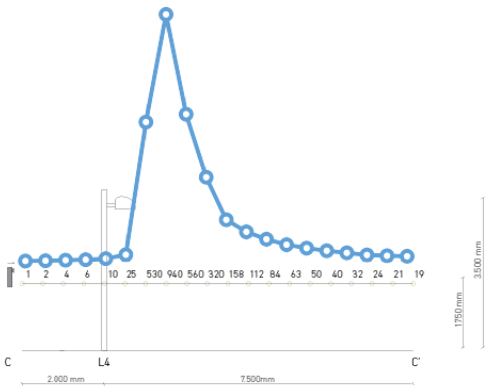


Figure 49. Elevation CC' Level 1

The lux measurements at zone two were taken the same procedure as in zone one. Measurements were registered for each elevation in two directions (C-C', C'-C, D-D', and D'-D,)

Elevation CC'

FACE level	Visualization on elevation CC'	
		C-C' Direction
		C'-C Direction

/ ZONE 2 - PHILIPS CITYSWAN BASIC

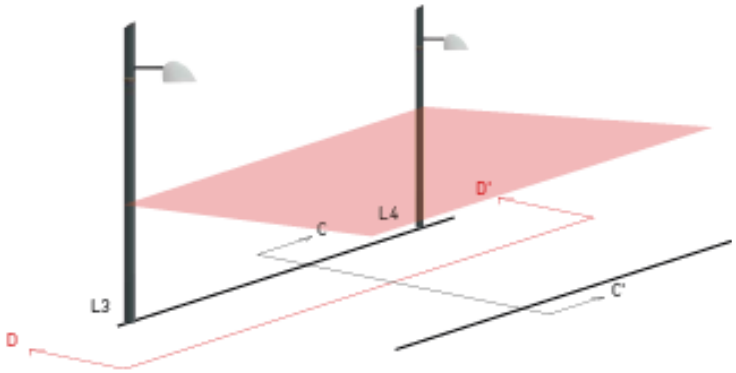
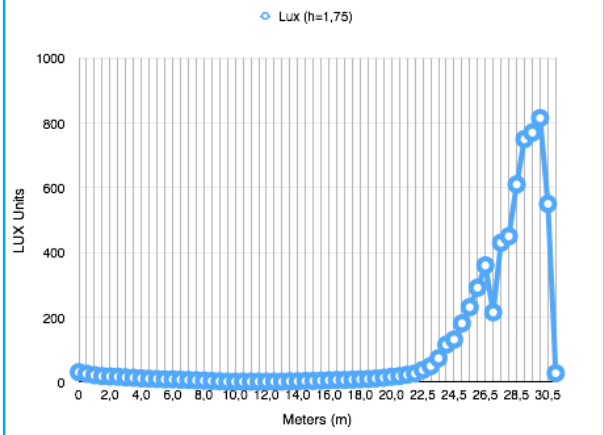
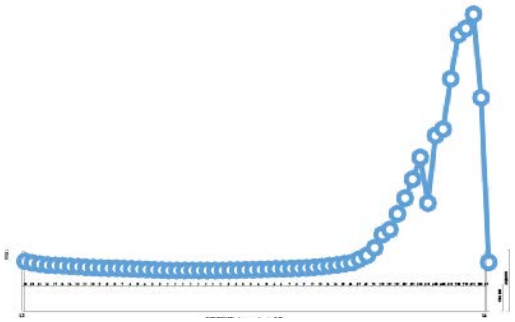
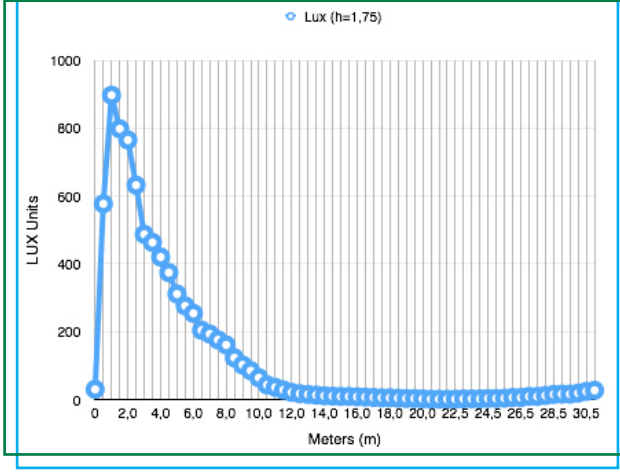
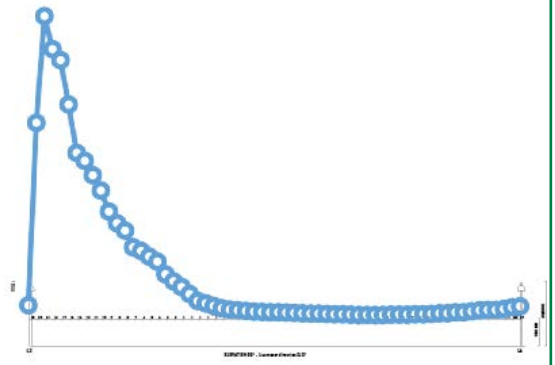


Figure 50. Elevation DD' Level 1

The lux measurements at zone two were taken the same procedure as in zone one. Measurements were registered for each elevation in two directions (C-C', C'-C, D-D', and D'-D,)

Elevation DD'

Face level	Visualization on elevation DD'	
		D-D' Direction
		D'-D Direction

Elevation CC'
There is registered a variation between lux ranges in the different directions, showing that the CitySwan Basic luminaire gather the highest values on the path zone when measuring the lux in a vertical axis at a height of 1.75m.
Considering both directions, the range of illuminance levels goes from 0lux to 940lux . On direction C'C values decrease considerably after the first 2 meters from L3 on the pathway.

Elevation DD'
Looking at the graphic results on the previous page, there is a drastic difference between values close to the luminaires and values at half of the distance between poles, even it follows a progressive lessening. On this elevation, the values range goes from 1 to 879lx.

The results from both elevations in Søndermarken, show that the average lux on a vertical axis at a height of 1.75m is 117,5lux, when calculating it with the values from both elevations.

RELEVANT FOR THE DESIGN:

- The lux distributuion of CitySwan Basic gives highest values on the path zone.
- CitySwan Basic use 24W to give an average of 117,5 lux at a height of 1.75m.

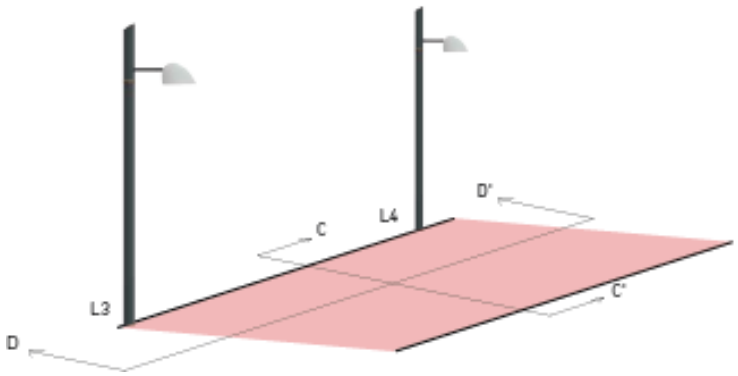
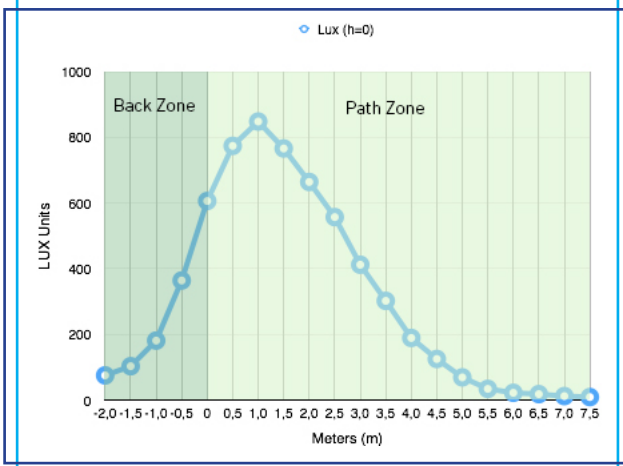
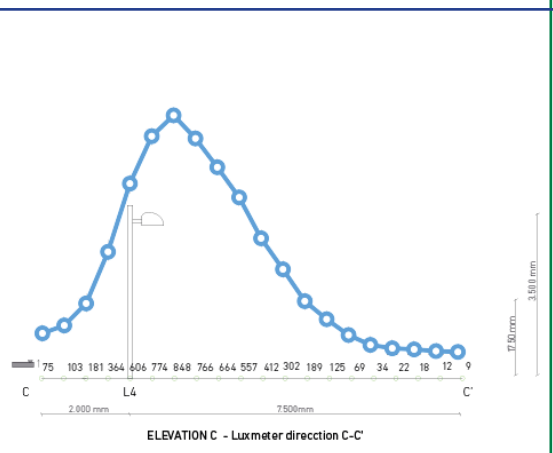
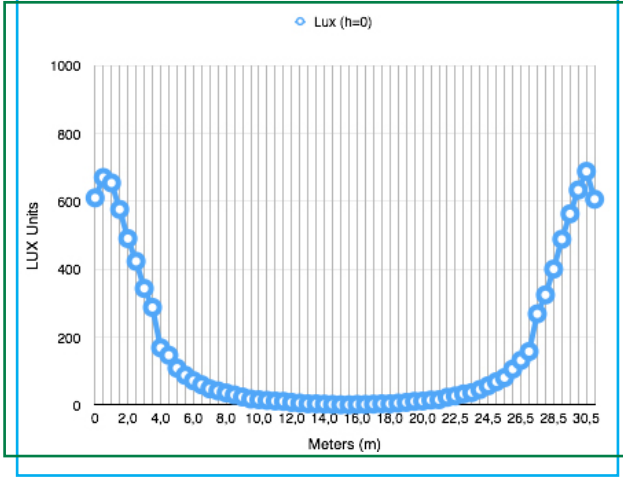
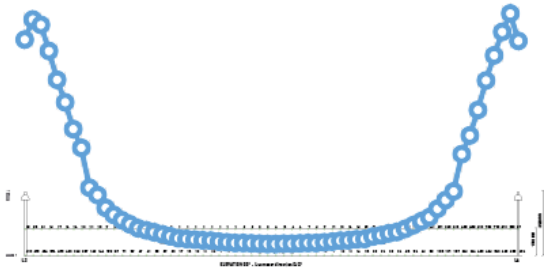


Figure 51. Elevations on ground level

GROUND level	Visualization on elevation	
		ELEVATION CC'
		ELEVATION DD'

GROUND Level conclusion

Observations on the light distribution conclude that Luminaire CitySwan Basic has an asymmetric radial expansion over the path zone. Lights values goes from 0 to 848lux. On the whole distance between poles, there is only registered zero lux for 1 meter at 15m from luminaire L3.

RELEVANT FOR THE DESIGN:
- CitySwan Basic gives asymmetric light distribution on ground level, focusing the highest levels on the pathway.
- Using 24W per luminaire the average Lux on ground is 205,2 lux
- If masts are in a distance of 30,5m, there is registered for 1meter values on 0 lux.

CONCLUSION SØNDERMARKEN lighting measurments

The light strategy used in Søndermarken consist in using different type of luminaries depending on the required functionality to increase the quality of the park for human activities, as also has been seen in Fælledparken. Even though the strategy in Søndermarken tries to minimized the impact in wildlife avoiding to lit all the pathsways, the design of the CitySwan bollard has a higher impact on wildlife than the ERCO IP65 used in Fælledparken. This higer impact is due the back-lighting, that although it keeps the highest values within the 1meter, the difference between both bollards is significant. On the other hand, the CitySwan gives a surrounding information to users increasing the safety feeling.

The mast CitySwan Basic offers a lighting distribution that covers all the pathway with lux over 1unit on ground and face level.

SUM UP RELEVANT FOR THE DESIGN:

- The lux distributuion of CitySwan Basic gives highest values on the pathway than on the backzone.
- CitySwan Basic use 24W to give an average of 117,5 lux at a height of 1.75m.
- CitySwan Basic gives asymmetric light distribution on ground level, focusing the highest levels on the pathway.
- Using 24W per luminaire the lux average on ground level is 205,2 lux
- If masts are in a distance of 30,5m, there is registered on the length of 1meter values with 0 lux.

5.5. UTTERSLEV MOSE

Utterslev Mose is a large semi-natural area located on the border between Copenhagen and Gladsaxe municipalities. It has an area of 200 hectares of which 97 hectares are covered by water. In Utterslev Mose there is population of wild birds, wildlife and nature.

People can practice a wide range of activities: outdoor pursuits, running, picnics, bonfires, hang-gliding, cycling, sunbathing, football matches and hiking. The following image (Figure 53) shows the map of the green area and located on it the zones for each activity.

Figure 52. Green zone reefers to Utterslev Mose location in the Copenhagen areal

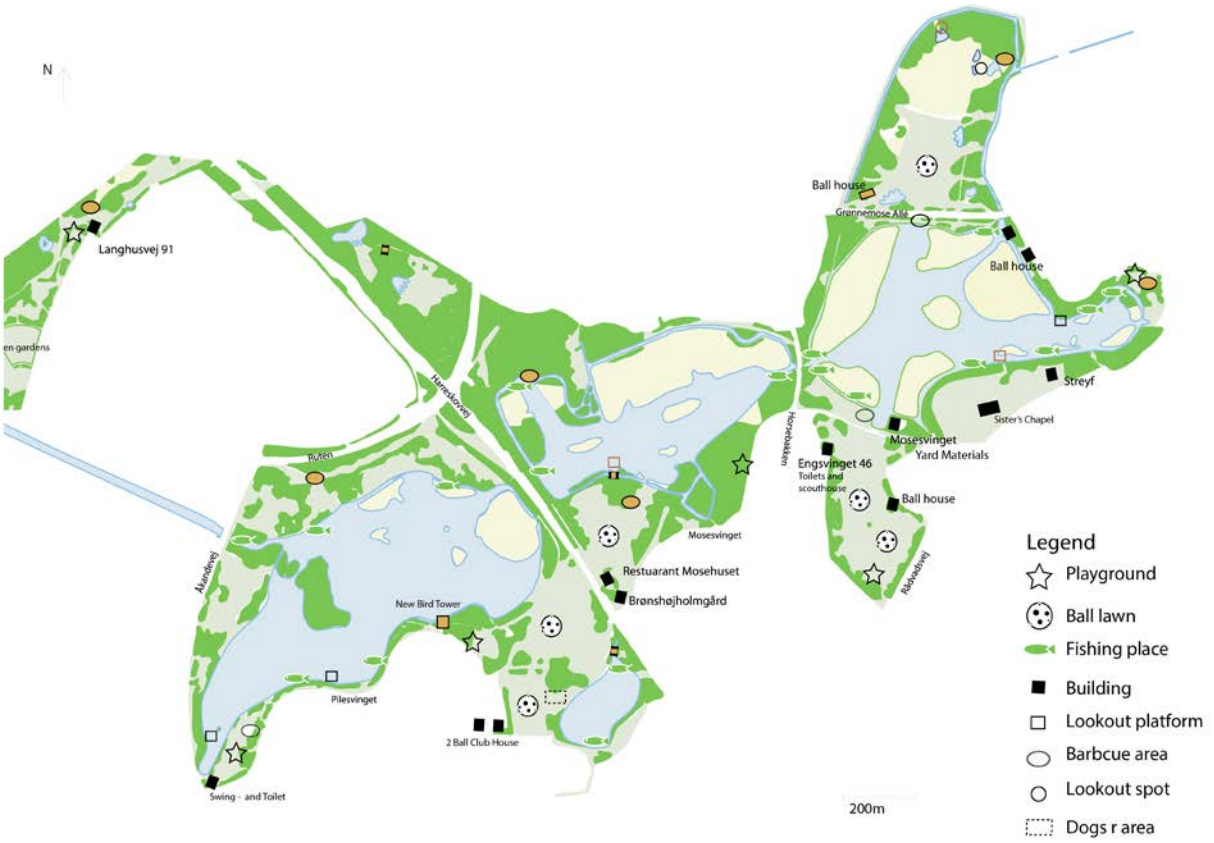


Figure 53. Map of Utterselv Mose

Utterslev Mose photographic report
Date: 25th of February.

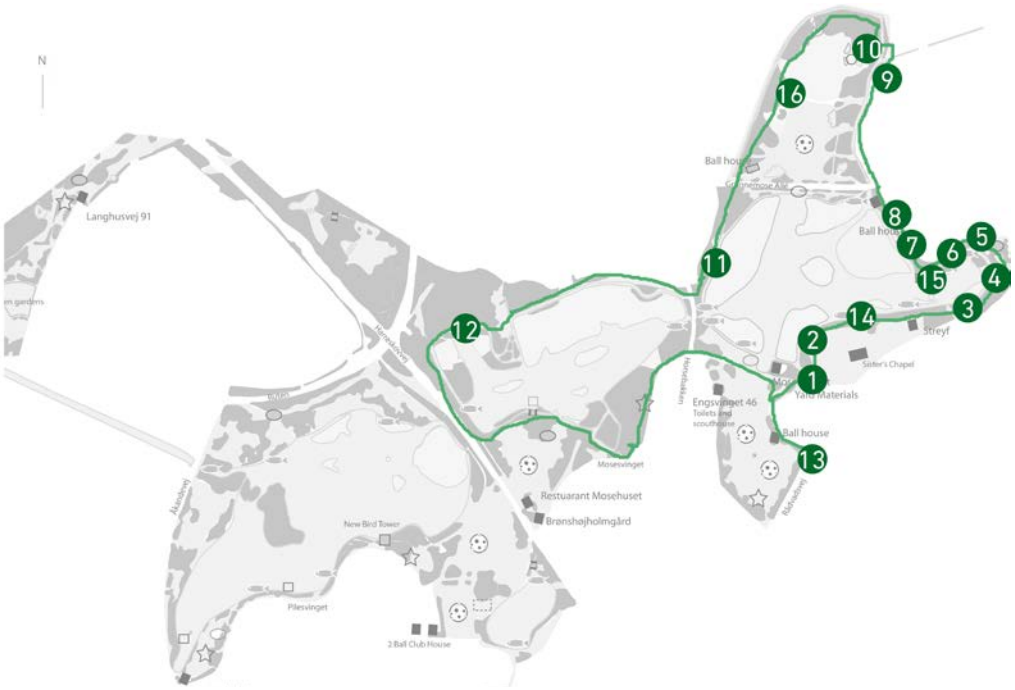


Figure 54. Route of the photographic report at Utterslev Mose


5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13


14


15


16

UTTERSLEV MOSE ANALYSES photographic report

The pictures date from on the 25th of February.

EXPERIENCE

The big dimensions of Utterslev Mose offer to users the possibility of disconnect from the city and merge into forest. The feeling of freedom and nature is in the air when walking through the area. The combination of lakes and the different vegetation from the surroundings, allow to host a wide range of wildlife that users can experience by walking along the paths.

The four lakes and two crossing roads divide the Utterslev Mose in different zones. Unfortunately, the roads break the harmony of the space having to watch out to walk from one side to the other side of the road to continue on your tour.

Although, It is a big green area, the fact that combines openings, as on picture 13 from the photographic report, and small paths, as picture 10, make this area a more interesting place to be and to discover while being in nature. In Utterslev Mose there are several areas for practicing exercises, however some of the zones do not present good conditions and seem careless, non inviting to people to use it.

LIGHTING SYSTEM

Utterslev Mose is a green area which is not provided with lighting system. During day time is a beautiful place to be, but when the night falls, It becomes extremely dark making users to feel unsafe around the area. The non existing lighting on paths, It is also a non existing lighting for activities areas as playgrounds, grill zone and It make users to leave the zone around sunset time.

RELEVANT FOR THE DESIGN:
- Freedom and nature in the air
- The green area is divided by lakes and roads.
- High biodiversity
- Big openings and narrow paths make the space interesting
- Unsafe feeling at night
- Darkness

UTTERSLEV MOSE Survey

A survey was carried out on the 25th and 26th of march of 2016 at Utterslev Mose. Users of the area were taking a survey of 10 several questions with 2 open questions in it.

The survey questionnaire can be seen on chapter 9.1 Survey

UTTERSLEV ANALYSES Survey

From the founding of the results can be conclude that the main user group of the area is people young people who use the area mainly for running and walk. Since there is an school close to the park , a lot of kids make us of the place to enjoy there free time. The results also show how people mainly use the area during day time, specially between 8am and 3pm, fact that can be due the lighting conditions since all of them coincide on a poor lighting and unsafe feeling during night time. A high percentage of users do not know about the existence of the interactive lighting system in Søndermarken, however they think that it must be an enjoyable tool.

Regarding the open questions about inputs for improving the area and observations, users seem to have an strong dependence of the daylight when going to the green area and the majority of them demand for a lighting system, since it would give them freedom on the time to use the area and it would increase the safety feeling .

To conclude the survey analyses, Utterslev Mose can be described as an area with high vulnerability to light pollution due its biodiversity, a big area to practice a wide range of activities and to experience nature. However citizens require for an illumination system to use the area when there is no daylight.

RELEVANT FOR THE DESIGN:
- Young people and kids using the area.
- Importance of a lighting system for users at night.
- High biodiversity.

UTTERSLEV MOSE technical measurements

Due the absence of lighting at Utterslev Mose, the lighting measurements of this green area are ignored leading an invalid quantitative research for this area. However, the qualitative research will be taken into account for further steps in the design process.

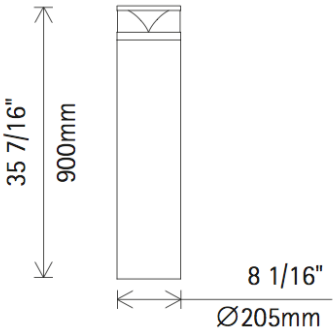
5.6 Comparison Technical Measurements

On the next pages there is calculated the light efficiency and the Watts per Km that each area use for each type of luminaire.

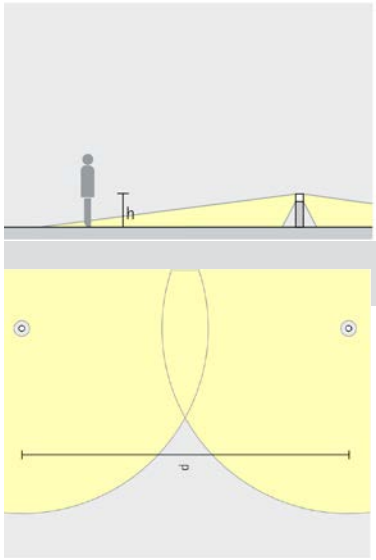
The coomparison starts showing the results of Fælledparken and Søndermarken when using a bollard luminaire and continues with the results of the two green areas when it is used a mast luminare.

FÆLLEDPARKEN light efficiency

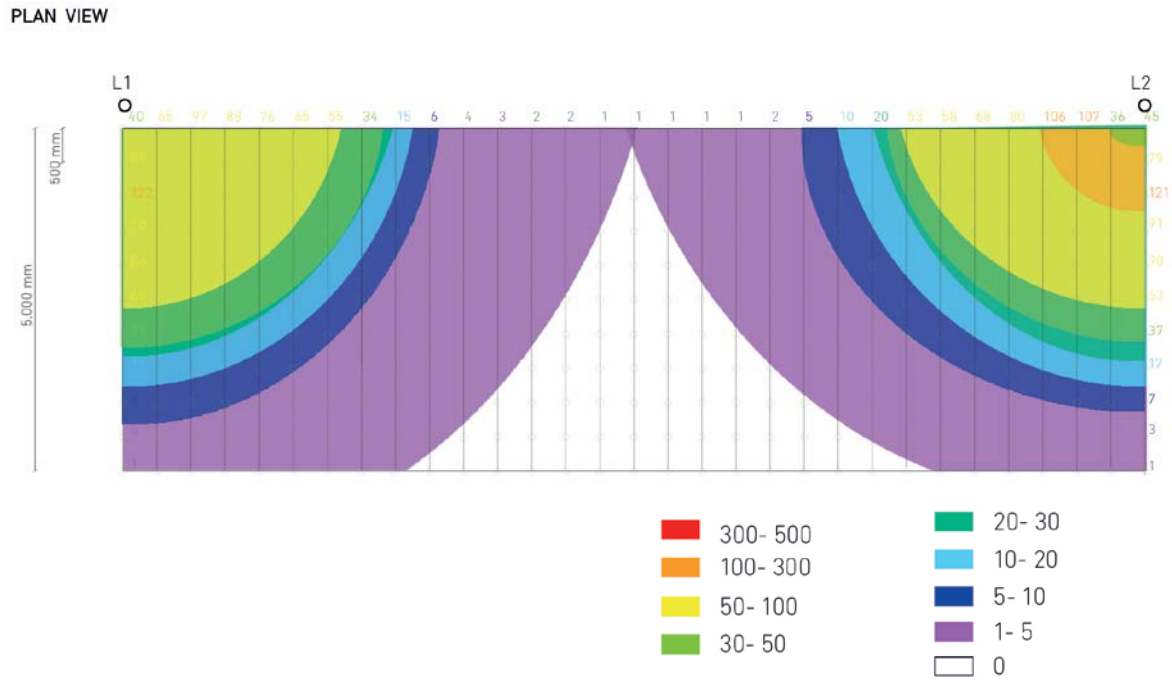
This sections study the Light Efficiency of the lighting system. Understanding as Lighting efficiency the ratio between the total luminous flux emitted by a device and the total amount of input power that it consumes. In SI, luminous efficacy has units of lumens per watt (lm/W). Photopic luminous efficacy of radiation has a maximum possible value of 683 lm/W, for the case of monochromatic light at a wavelength of 555 nm (green).



Luminaire	ERCO IP65	
Color temperature	4000	K
Luminous flux of the luminaire	617,0	lm
Power	27,0	W
Luminous efficacy	22,7	lm/w
Luminous efficiency	3,3	%
Distance between bollards	15,0	m
Height of source	0,9	m
Average Lux on ground level	58,9	lx
Average Lux on face level	4,4	lx
Number of luminaire per km	134	luminaires/km
Watts per km	3.618	W/km

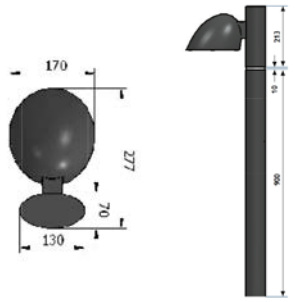


LUX DISTRIBUTUION ON GROUND LEVEL

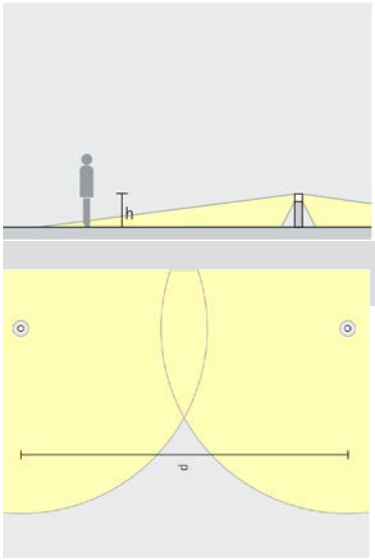


SØNDERMARKEN light efficiency

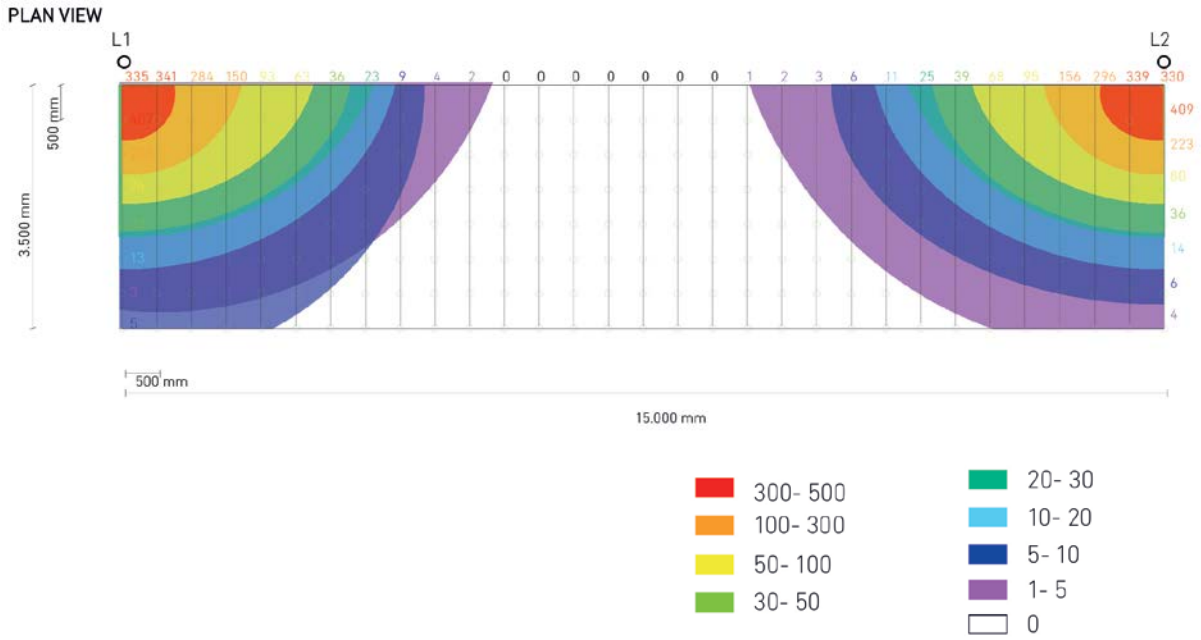
This sections study the Light Efficiency of City Swan luminaires of the Søndermarken lighting system.



Luminaire	CitySwan Bollard	
Color temperature	3000	K
Luminous flux of the luminaire	380,0	lm
Power	7,0	W
Luminous efficacy	54,3	lm/w
Luminous efficiency	7,9	%
Distance between bollards	15,0	m
Height of source	1,07	m
Average Lux on ground level	95,6	lx
Average Lux on face level	4,3	lx
Number of luminaire per km	134,0	luminaires/km
Watts per km	938,0	W/km

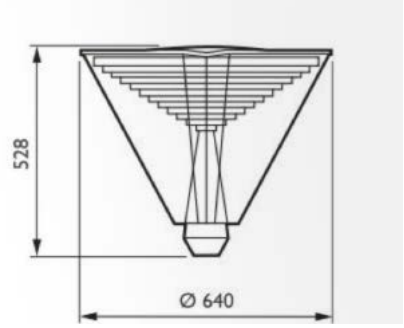


LUX DISTRIBUTUION ON GROUND LEVEL

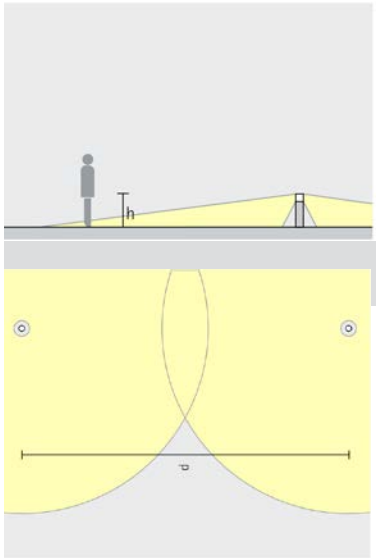


FÆLLEDPARKEN light efficiency

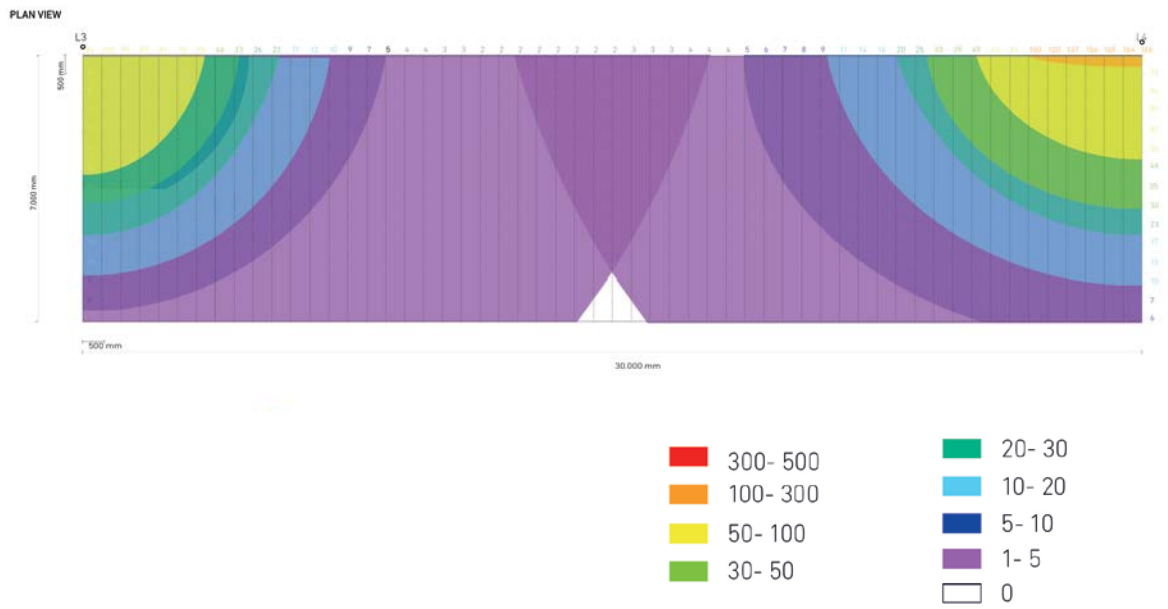
This sections study the Light Efficiency of the Fælledparken lighting system when using Philip Park luminaries.



Luminaire	Philips Park
Color temperature	4000 K
Luminous flux of the luminaire	3614 lm
Power	58 W
Luminous efficacy	62,3 lm/w
Luminous efficiency	9,1 %
Distance between bollards	28,0 m
Height of source	4,0 m
Average Lux on ground level	61,0 lx
Average Lux on face level	26,0 lx
Number of luminaire per km	72,0 luminaires/km
Watts per km	4176,0 W/km

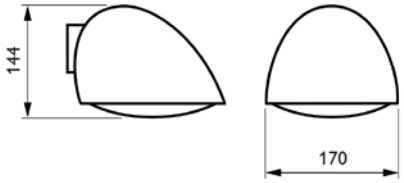


LUX DISTRIBUTUION ON GROUND LEVEL

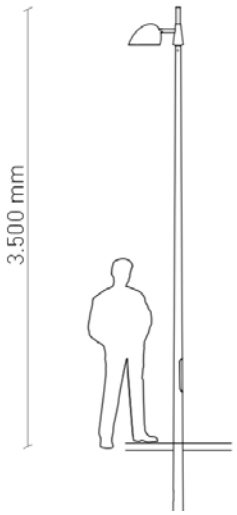


SØNDERMARKEN light efficiency

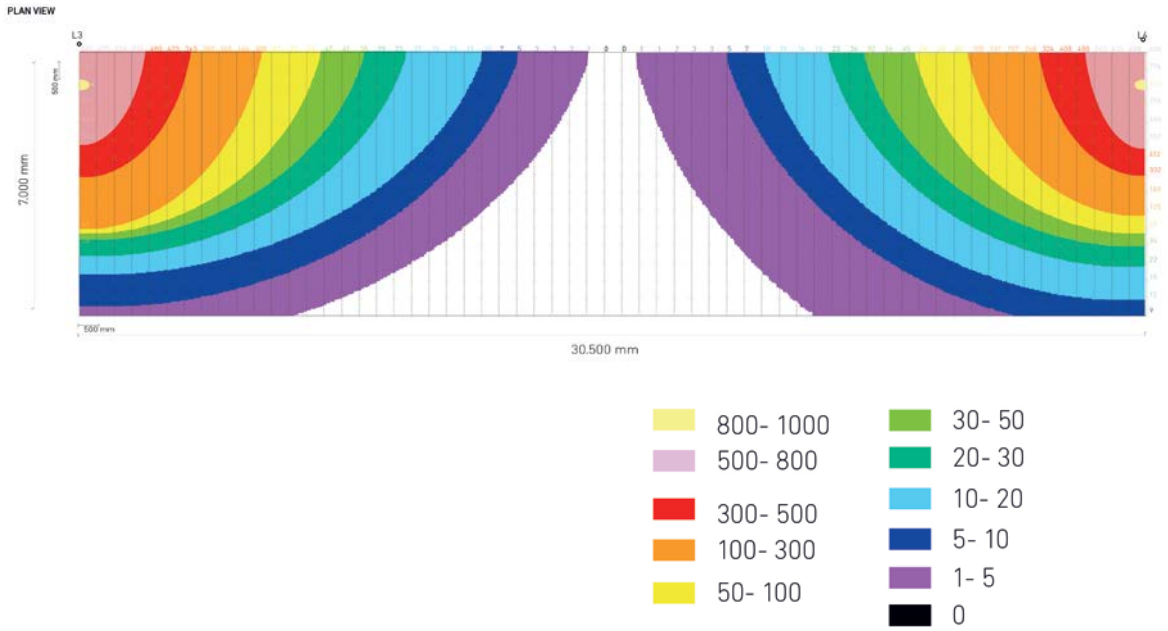
This page gather the technical information of City Swan basic luminaires from Søndermaken lighting system.



Luminaire	CITY SWAN BASIC
Color temperature	3000 K
CRI	80
Luminous flux of the luminaire	2260,0 lm
Power	24,0 W
Luminous efficacy	94,1 lm/w
Luminous efficiency	13,7 %
Distance between bollards	15,0 m
Height of source	0,9 m
Average Lux on ground level	205,2 lx
Average Lux on face level	117,7 lx
Number of luminaire per km	65,0 luminaires/km
Watts per km	1.560 W/km



LUX DISTRIBUTUION ON GROUND LEVEL



5.7 Conclusion Technical measurements

BOLLARD	ERCO IP65 	Color temperature	4000 K
		Luminous flux of the luminaire	617,0 lm
		Power	27,0 W
		Luminous efficacy	22,7 lm/w
		Luminous efficiency	3,3 %
		Distance between bollards	15,0 m
		Height of source	0,9 m
		Average Lux on ground level	58,9 lx
		Average Lux on face level	4,4 lx
		Number of luminaire per km	67 luminaires/km
		Watts per km	1.809 W/km
	CitySwan 	Color temperature	3000 K
		Luminous flux of the luminaire	380,0 lm
		Power	7,0 W
		Luminous efficacy	54,3 lm/w
		Luminous efficiency	7,9 %
		Distance between bollards	15,0 m
		Height of source	1,07 m
		Average Lux on ground level	95,6 lx
		Average Lux on face level	4,3 lx
		Number of luminaire per km	67 luminaires/km
		Watts per km	469 W/km
MAST	Philips Park 	Color temperature	4000 K
		Luminous flux of the luminaire	3614 lm
		Power	58 W
		Luminous efficacy	62,3 lm/w
		Luminous efficiency	9,1 %
		Distance between mast	28,0 m
		Height of source	4,0 m
		Average Lux on ground level	61,0 lx
		Average Lux on face level	26,0 lx
		Number of luminaire per km	36 luminaires/km
		Watts per km	2.088 W/km
	CitySwan Basic 	Color temperature	3000 K
		Luminous flux of the luminaire	2260,0 lm
		Power	24,0 W
		Luminous efficacy	94,1 lm/w
		Luminous efficiency	13,7 %
		Distance between mast	30,5 m
		Height of source	0,9 m
		Average Lux on ground level	205,2 lx
		Average Lux on face level	117,7 lx
		Number of luminaire per km	33 luminaires/km
		Watts per km	792 W/km

CONCLUSION light efficiency

BOLLARD

Looking at the results it was found out that in Fælledparken, using ERCO IP65, a power consumption of 1.809 W per km, results in an average illuminance of 58,9lx on the ground level. The vertical illuminance on a height of 1.75m for facial recognition is 4,4lx in average. This gives an illuminated pathway with values over 1lx with an homogeneous lit.

Using the same type of bollard but a CitySwan Philips luminaire, in Søndermakren, the lighting consumes 469 W per km of pathway, resulting in a higher average illuminance of 95,6lx on the ground. The vertical illuminance on a heigh of 1.75 for facial recognition is 4,3lx, around the same illuminances than in Fælledparken.

Therefore with a consumption of just 25,9 % of electricity, the lighting in Søndermarken is achieving higher illuminances on ground level. However the lighting is not that homogeneous as in Fælledparken and It creates black spaces on the pathway with illuminances under 1lx.

The result is caused by the same spacing of less powerful luminiares with just 380 lumen compared to the more powerful ones used in Fælledparken, featuring 617 lumen.

MAST

Looking at the results it was found out that in Fælledparken, using Philips Park, a power consumption of 2.088,0 W per km, results in an average illuminance of 61 lx on the ground level. The vertical illuminance on a height of 1.75m for facial recognition is 26 lx in average. This gives a illuminated pathway with illuminances over 2lx and a more evenly lit with mainly no vertical illuminances under 1lx.

Using the same type of luminaire but a CitySwan Basic, in Søndermakren, the lighting consumes 792,0 W per km of pathway, resulting in a higher average illuminance of 205,2lx on the ground. The vertical illuminance on a heigh of 1.75 for facial recognition is 117,7lx, a 22% more than Fælledparken.

Therefore with a consumption of just 37,9 % of electricity, the lighitng in Søndermarken is achieving higher illuminances on ground level. However the lighting is not that homogeneous as in Fælledparken and It creates black spaces on the pathway with luminances under 1lx.

The result is caused by the bigger spacing of less powerful luminiares with just 2260 lumen compared to the more powerful ones used in Fælledparken, featuring 3614 lumen and a reduction of the distance between mast of 2,5m.

6. DESIGN

6.1 GLOBAL CONCEPT

The global concept was created after carrying out the photographic report and the survey of each green area. From the analyses it was found out that people is interested in colours and they like to enjoy them while relaxing, running or walking in nature.

"Copenhagen city hall should plant more variety of trees and flowers in the park"
" I come to park because I like to see the colours of nature"

Inspirational comments as the above kept the attention on how to enhance nature and how people can experience its beauty during the whole year. From there, the global concept was stablish for the Utterslev Mose lighting system.

The Seasons

Every year the earth experience changes in nature going through the 4 different season: Spring, Summer, Autumn and Winter. Each season is characterized by some colours that define its beauty. These colours come from nature which is in continuous changing all over the year, as a wheel in motion.

A good way to describe and visualize these changes is by imagine a Tree in a forest, which goes through different states; at the beginning of the summer it spreads its most powerful and fresh green colour. Although, when the summer ends and the autumn shows up, the leaves of the Tree turn brownish until they fall covering streets and forest grounds. Days become shorter and autumn brings with it, a romantic atmosphere on the air that soon it is erased for the white and cool landscapes from winter. The snowflakes fall over the Tree and it covers all its branches during this freezing period of the year. Suddenly, there is no more snow and the hours of daylight increase. The sun is shining and small and green leaves appear again on the tree, announcing that Spring has arrived.

The described nature cycle happens due the rotation of the Earth around the Sun, which effects nature by the light that it spreads changing the angle of incidence at each solstice, which also provokes variations in the amount of daylight at each place in the Earth.

Figure 55 . Solstice and sun incidence

GLOBAL CONCEPT INTO CONTEXT

Utterslev Mose

The change of the nature's colours in each season has been studied and visualized for years in Color Wheels. The reason why nature change colour is because of the different plants that can be found in each solstice. (See Figure 56)

Combining the colour wheel that correspond to each season with the nature of this study case, defines the design concept for Utterslev Mose. This concept supports nature by enhancing the nature colours in each season bringing and smooth colour transition through the year Utterslev Mose will be illumianted with the colour of flowers.

Figure 56. Nature wheel

6.2 LIGHTING CONCEPT

Interactive Nature Wheel for Utterslev Mose

The lighting concept for Utterslev Mose it is based on the global concept presented, where the colours of the season and the seasonal plants are taking a roll. The combination of both gives as a result the lighting system for Utterslev Mose which consist of three layers of lighting.

LAYER 1 - General Lighting

The first layer of the scheme is the general lighting, which follows a lighting strategy based on bollards and mast, used in pathways or specific zones respectively. The lighting system avoid to lit surrounding or having any unnecessary light that could contribute to increase the impact in wildlife.

The decision of selecting this types of luminaries lies on the results of the analyses of the technical measurements. The results showed that the usage of bollards provides enough light to see the faces of people walking , at the same time that it has a minor impact on airspace. This type of lighting will be used around the area periphery. The smaller interconnections between inner paths are kept in darkness to minimize the light pollution.

Following Fælledparken and Søndermarken strategy, mast luminaries will be used, at entrances and playgrounds or exercise zones, since they need to provide more spatial light.

LAYER 2 - Intelligent Lighitng

As observed in Søndermarken, the lighting system will have and interaction, but in this case will be between nature and light. The peripheral paths will have an interactive lighting system which will change colour according to the seasonal colour wheel. The transition between colours will be smoothly, as smooth travel the seasons through the year. The colour of light will be in constant changing even It can not be experienced in a short term.

The lighting colour used around each of the three lakes, will be defined for the colour of an specific plant of the season. The Utterslev Mose area will be divided in three blocks which are defined by the three lakes. All the playgrounds or exercise zone in each block will share the same RGB color , and they will change through the year representing a different plant in each season. This means that each block will change over the year in 4 different colours that will represent 4 different plants. The transition between colours would be smooth and in the same colour range.

LAYER 3 - Accent lighting

Lighting for big sport areas like the football courts will have specific down-lights to cover the needs of the users when it is required.

6.3 IMPLEMENTATION

LAYER 1 - General Lighting

The general lighting use bollard and mast luminaries. The first ones to illuminate the surrounding pathways and the second ones for specific zones, as playgrounds or exercise areas.

The following map, (Figure 57), shows the location where these two types of lighting will be placed. The exactly amount of luminaries will be defined for the product selected, which will be specified on the next chapter 6.4 Lighting fixtures.

Figure 57. Position of luminaries.

- Bollard luminare
- Mast luminare for lighting exercise and playground zones
- Special luminaire for sport court.

LAYER 2 - Intelligent Lighting

The second layer is inspired by the interaction between people and light that offers Søndermarken. From the Survey it was found out that people like that Søndermarken presents a lighting interaction, but at the same time, the majority of the users do not make use of it. That is the reason why the lighting for Utterlsev Mose, instead of searching for an interaction between people and light, it looks for an intelligent system that can enhance nature and support it with its changing colours through out the year.

The lighting uses an integrated system that allows to control the RGB of the luminaries. It change the colour in the same speed that the seasons pass through the year. The speed and the colour range is programmed for each season in three different control box.
Three boxes, one for each lake, where there will be running a different range of colours inside the same season pallet.

This intelligent lighting will control the bollards on the peripheral paths as well as the mast at the exercise areas to be in accordance around each lake. This will create an harmonious design for each area under the unique global atmosphere of the whole green area.

Figure 58. The three areas that correspond to the three lakes

The intelligent lighting of this project is defined by a lighting scheme controlled by wifi. It consist in two levels of control; global and local. The global control consist on having the bollards and the mast luminaries that corresponds to each area connected to the same control system. On the other hand the local control is in each bollard, where a motion sensor will allow to dim or increase the light when it is required. For an easier understanding, the following picture simplify the technical system.

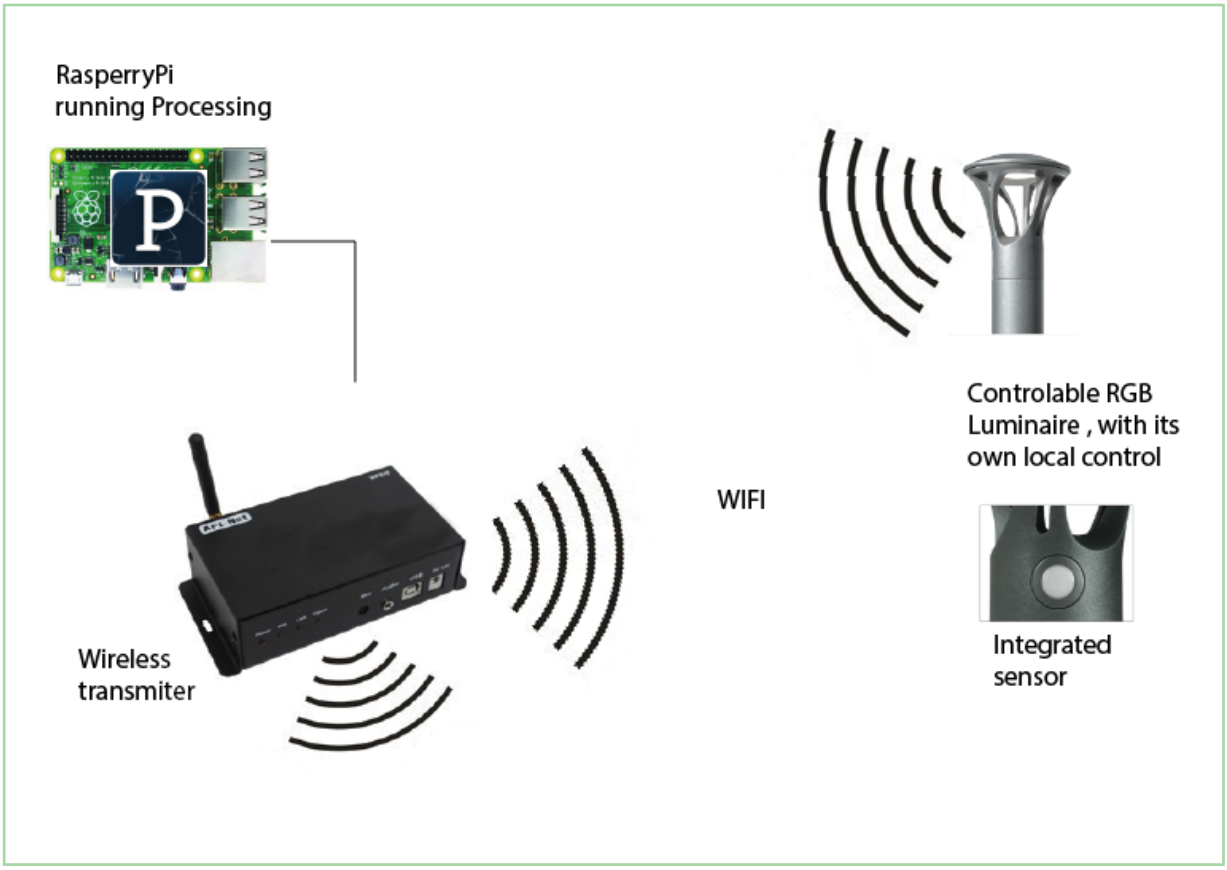


Figure 59. Scheme of the intelligent lighting

There are 3 Control Box , one for each lake zone. Inside each Control Box there is a Rasperry Pi and a wireless transmitter. The RasperryPi allows to control the information of the luminaries from everywhere since the information can be change through a link in internet. Rasppery Pi is running a processing program, in which a code specifies that everyday of the year corresponds to a new RGB Color and after changing the colour for that day the signal is send to the transmitter which forward the signal by wifi to the luminaires. The luminaries has an integrated communication module that allows to read the signal and then the controller commands over the RGB led. Inside each luminaire there is an integrated motion sensor to dim or increase the amount of light when it is required. This is controlled in the local luminaire since it is not desired that the command affects the whole system.

The photographies on the next page were taken at Utterslev Mose by the author of the project on each season. The pictures will determinate the colours that will be used in the design.

The procedure to obtain the colours consist on observing the two pictures of each season an extract three colours that are related to three plans, flower or any type of nature that can be found on the correspondent season in Utterslev Mose.

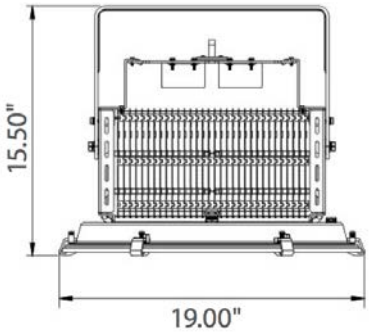
	PHOTO 1	PHOTO 2	COLOR		
SPRING				R:239 G:229 B:235	H:324 S:4 B:94
				R:222 G:199 B:213	H:323 S:10 B:87
				R:207 G:170 B:191	H:326 S:18 B:81
SUMMER				R:214 G:251 B:189	H:96 S:25 B:98
				R:187 G:211 B:151	H:84 S:28 B:83
				R:130 G:153 B:92	H:83 S:40 B:60
AUTUMN				R:237 G:187 B:113	H:36 S:52 B:93
				R:204 G:151 B:106	H:28 S:48 B:80
				R:160 G:108 B:84	H:13 S:41 B:63
WINTER				R:198 G:215 B:240	H:216 S:18 B:94
				R:172 G:184 B:207	H:219 S:17 B:81
				R:103 G:111 B:138	H:226 S:25 B:54

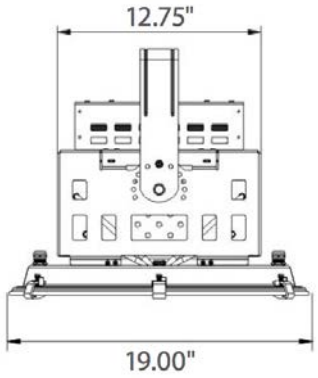
LAYER 3 - Accent lighting

The fourth layer of the lighting design is regarding sports lighting. Since in Utterlsev Mose there are several courts for football, It has been decided that It would be only the main football court illuminated in order to avoid a higher impact in wildlife due the high amount of lumen coming out from this type of fixtures. Moreover, lighting only one court, it will also minimize the aerial pollution since they are normally placed in high height.

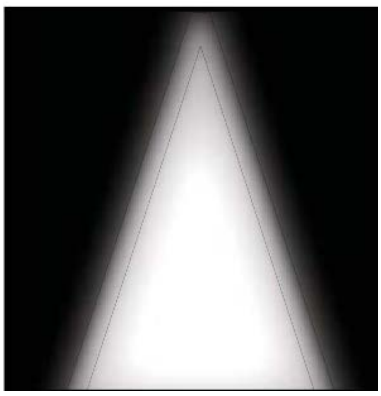
The selected court area can be seen on the map at the introduction of this chapter and the lighting fixture will follow a similar characteristics as the example of figure 60. In this project we will not detail the amount and the fixture type for this lighting, since sports lighting it is not the aim of this project. However, the next images presents a plausible example that for this situation.

Neptun lighting
LED-SL60-250-UNV





60° Beam



Model No.	Description	Rated Watts	Input Watts	Initial Lumens
LED-SL60-250-UNV	LED Sports Lighter	250	252	25,000

Figure 60. Plausible luminaire

6.3 LIGHTING POSITION TECHNIQUE

The strategy used in the lighting design for Utterslev Mose follows the usage of two types of luminaires, bollard and mast, as it has found out from the Fælledparken and Søndermarken analyses.
The division of the zones where each type of luminaire will be placed has been already presented in the previous chapeter Layer 1- General lighting. Testing luminaires in Dialux program is the next step on finding out the desire lighting distribution and efficiency. The testing process take into account the possibility of using the current studied luminaires of Fælledparken and Søndermakren. Although it will test the same luminaire, it will apply a new technique by changing positions of bollards. This change could bring a beneficial combination between efficiency, needs of users and wildlife impact.

BOLLARDS Testing

CitySwan test
Starting from the analyses conclusion where the CitySwan and the Erco Panorama where studied, it was found that, even though CitySwan is using less power, only 7W, the light distribution on the floor is not that even as what Erco can offer when the bollards are displayed in the same distance of 15 meters. Moreover, the high differences between lux values on ground level can make difficult the adaptation process to darkness.

Erco use1.809 W/km when the bollards are in a distance of 15meters. Using this product, it is not possible to increase the distance between bollards, if black spaces on the floor are not desired. It has been proved in the analyses that ERCO Panorama covers the floor with illuminance levels over 1lux, except for an small area at the middle distance and at the opposite side of the pathway, where values were registered under 1lux. If there is no possibility of reducing the distance, there is no possibility of reducing the power consumption using this exact luminaire.

On the other hand, it is possible to bring a similar light distribution on the floor using less power by placing CitySwan in a distance of 10 meters. The distance is reduced while the power consumption increase, at the same time that improve the even light distribution on the ground level and for facial recognition. Using this technique the power consumption used for kilometer is 700 W, still 61,3% less than using Erco Panorama. Comparing these two luminaires, to use CitySwang would be the better solution regarding power consumption and users needs.

However, the results of the analyses shown that CitySwan has a high lux level during the first meter on the back side of the luminaire. Having a back-lighitng can be beneficial for users in Utterslev Mose since it will give them information of the surrounding.

The possibility of CItySwan in RGB was confirmed by Philips and it make the luminaire as a plausible solution for Utterslev Mose lighting system.

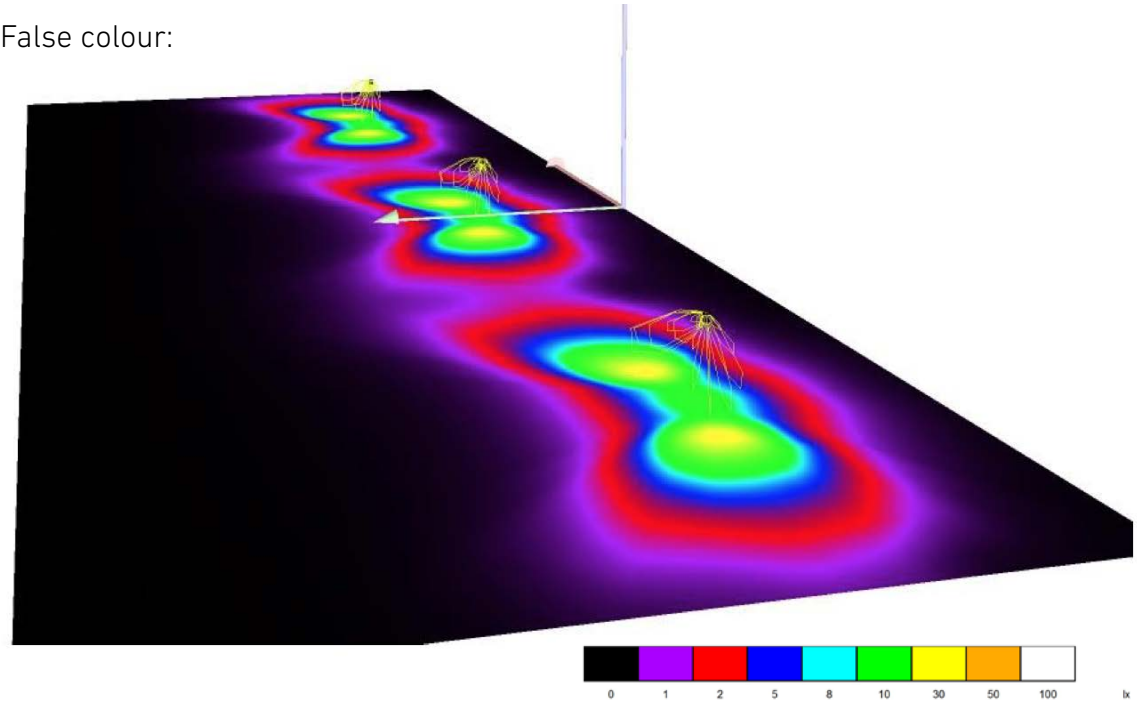
To evaluate CitySwan solution a 3D model in Dialux was done. The luminaires were placed at 10m from each other and the path width was 3m.

TEST 1

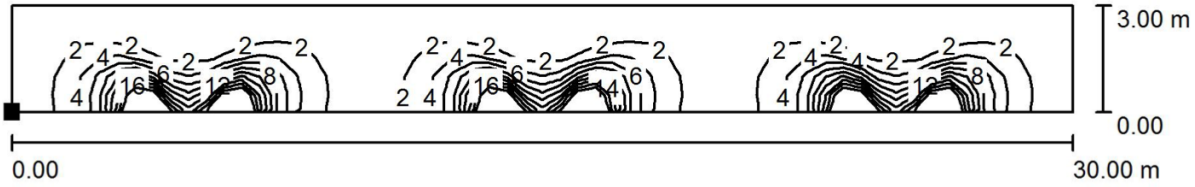
CitySwan in a 10meter distance between bollards has been test in a 3D model in DIALUX.

Source Height: 914mm

3D False colour:



Lux distributuion on a plan view:



Lux ground level:

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]
4.04	0.21	32

Lux Semy-cylindrical h:1,75:

E_{av} [lx]	E_{min} [lx]	E_{min} [lx]
0.21	0.20	0.20

Looking at the false colour image and the lux distribution on the ground level obtain from DIALUX, is possible to appreciate how the problem of dark spaces between luminaries is solved by placing one bollard every 10 meters. The lux levels become more evenly distributied and the average of illuminances 4.04lx.

Eaton Invue ARBOR test

Although CitySwan was evaluated as a possible solution, It was interesting to study more possibilities with luminaires on the market before choosing the final luminaire for Utterslev Mose.

After some research the most suitable product was Eaton's Invue Arbor bollard. It offer a family of LED luminaires that uses seamless organic design elements, inspired by nature. (figure61 and figure 62)

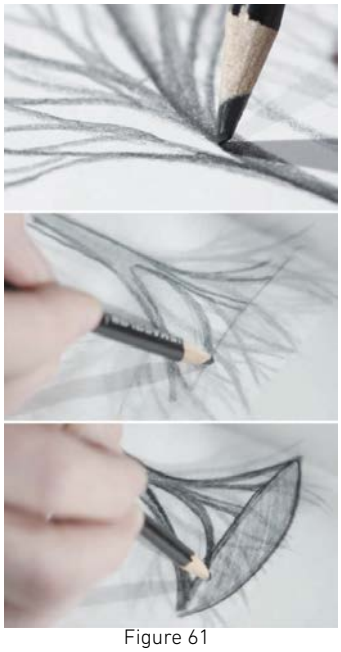


Figure 61

This luminare has also integrated a sensor for reducing consumption. It enabled solutions with integral 0-10V dimming drivers that can be controlled by external systems or through photocontrol receptacles. It has integrated controls as standalone occupancy sensors, DALI drivers, twistlock or button type photocontrols and connected solutions as LumaWatt which utilize wireless communication to control and monitor lighting through an intuitive graphical interface, via the internet in real time.

Figure62.Sensor

The luminaire offer different possibilities with symmetric and asymmetric optics which is really interesting due the different type of paths that has Utterslev Mose (one way, doble pathway..). It also offer colour temperatures of 4.000K and 3.000K. After contacting the company having luminaries in RGB it could be possible.

The specifications of the luminarie and the options are on figure 63.

Bollard

POWER AND LUMENS

Lumen/Distribution	B1 Symmetric	B2 Symmetric	B1 Assymetric	B2 Assymetric
Drive Current				
Power Wattage (Watts)	16W	32W	11W	23W
Input Current (mA) @ 120V	140	270	100	200
Input Current (mA) @ 208V	80	160	60	120
Input Current (mA) @ 240V	70	140	50	100
Input Current (mA) @ 277V	60	120	40	90
Power Wattage (Watts)	19W	37W	13W	27W
Input Current (mA) @ 347V	60	110	40	80
Input Current (mA) @ 480V	180	320	120	240
Optics				
Lumens	717	1,276	472	848
BUG Rating	B1-U0-G1	B1-U0-G2	B1-U0-G1	B1-U0-G2

Figure 63

After considering EATON as another possible solution for the design, it was necessary to test it in DIALUX in order to study the illuminance on the ground level. The product is available in different optics and settings. Therefore after looking at the variety of paths found in Utterslev mose, asymmetric and symmetric optics were selected to be tested.

The next fourth images shown the type of paths of Utterslev Mose , considering to use B2 Symmetric, in pathways as figure 64 and 65, and B1 asymmetric in pathways as figure 66 and 67 where the difference with the paths levels is highly pronounced.

Figure 64

Figure 66

Figure 65

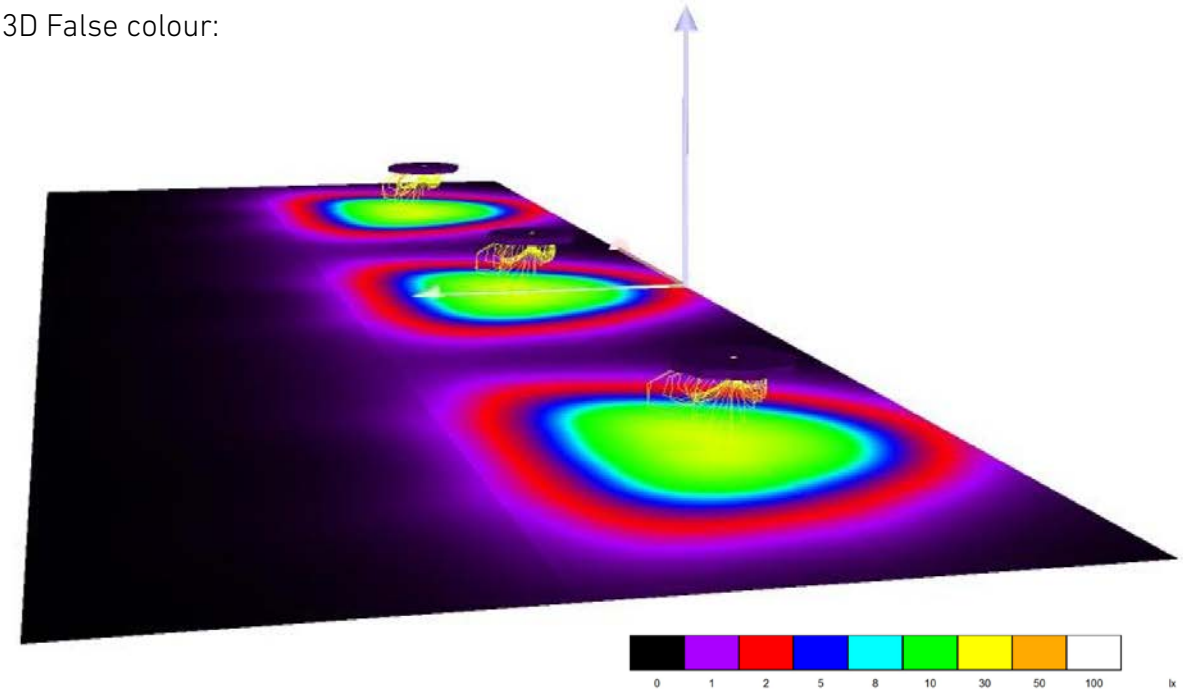
Figure 67

To test the luminaries a simple 3D model was done in Dialux to analyse illuminances on ground level and for face recognition. To defined the height of the light source the first test was done in two of the heights that the luminaire is available: 914mm and 1070mm. The path width has been taken as 3meters.

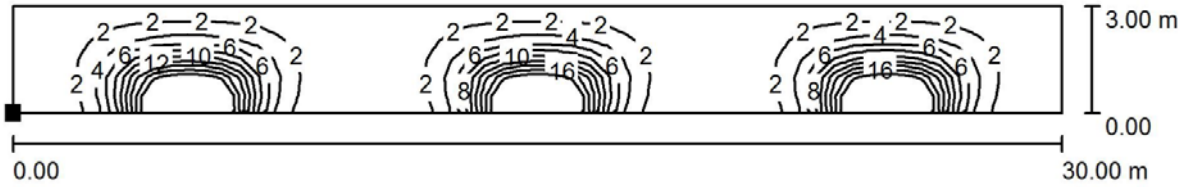
TEST 2 - Asymmetric in two different height:

Source Height: 914mm

3D False colour:



Lux distributuion on a plan view:



Lux ground level:

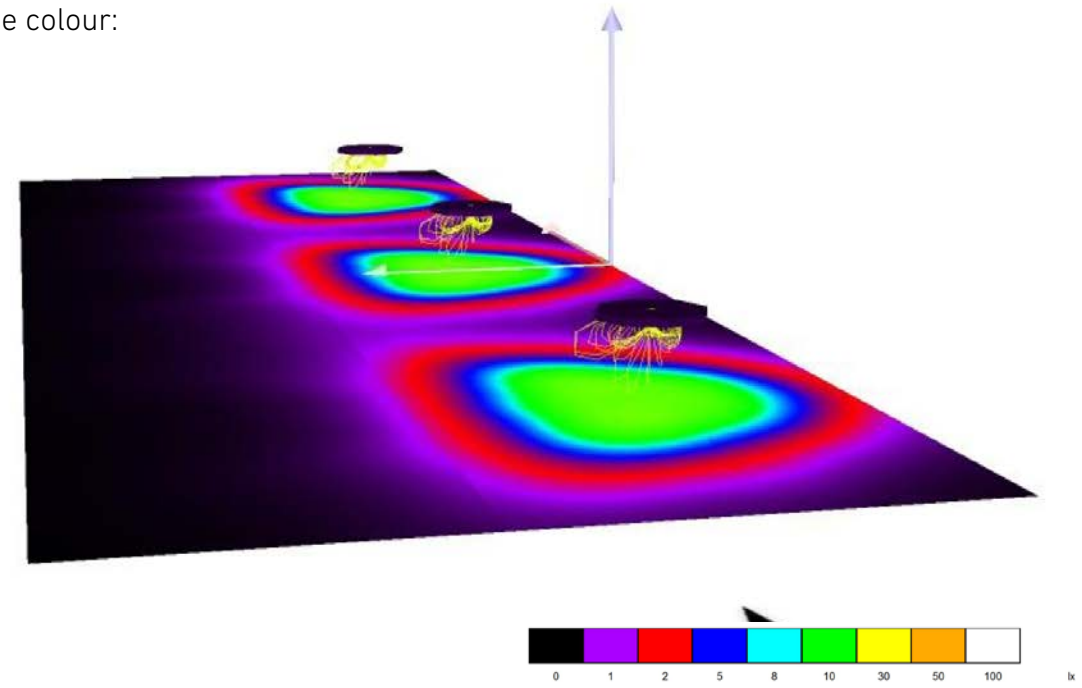
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]
5.24	0.28	26

Lux Semy-cylindrical h:1,75:

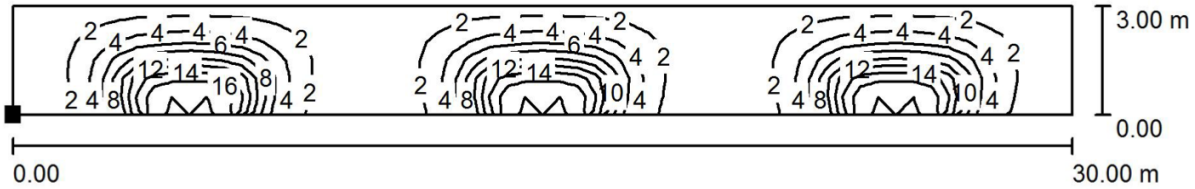
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]
0.26	0.26	0.26

Source Height: 1070mm

3D False colour:



Lux distributuion on a plan view:



Lux ground level:

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]
5.10	0.45	18

Lux Semy-cylindrical h:1,75:

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]
0.29	0.28	0.29

Looking at the Dialux results the average lux between both heights does not present relevant differences. Taken into account the preferences on do not disturb wildlife, the chosen height was H.914mm.

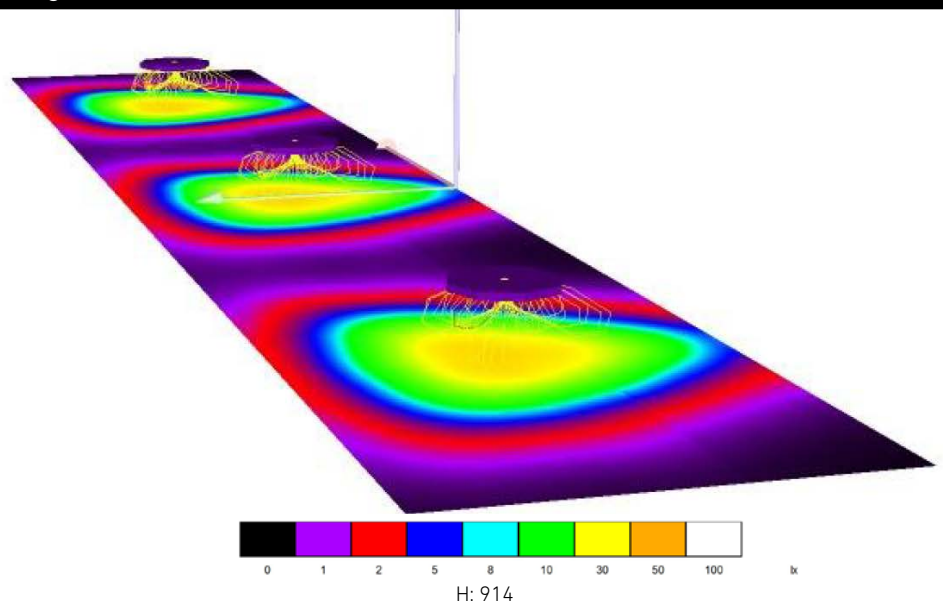
On the next page would be evaluated the dialux results between CitySwan and Eaton's Invue Arbor, in order to choose the luminaire that would be in the design.

Another test was carried out to test symmetric optics for luminaires when they are located in double pathways. This position of the bollards gather the majority of the light on the pathway minimizing the amount of light that affects directly to wildlife.

TEST 3

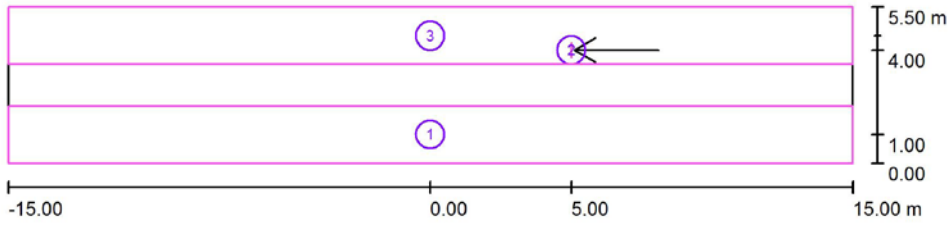
Symmetric

Source Height: 914mm



H: 914

Exterior Scene 1 / Calculation surfaces (results overview)



Scale 1 : 215

Calculation Surface List

No.	Designation	Type	Grid	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
1	Path surface	horizontal	60 x 6	4.54	0.10	31	0.021	0.003
2	Face	semi-cyl., 0.0°	60 x 6	0.37	0.37	0.37	1.000	1.000
3	Path surface	horizontal	60 x 6	5.02	0.31	30	0.062	0.010

Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
horizontal	2	4.78	0.10	31	0.02	0.00
semi-cyl.	1	0.37	0.37	0.37	1.00	1.00

COMPARISON

CitySwan 	Luminous flux of the luminaire	380,0	lm
	Power	7,0	W
	Luminous efficacy	54,3	lm/w
	Luminous efficiency	7,9	%
	Distance between bollards	10,0	m
	Height of source	1,07	m
	Average Lux on ground level	95,6	lx
	Average Lux on face level	4,3	lx
	Number of luminaire per km	100	luminaires/km
	Watts per km	700	W/km
Eaton's Invue Arbor 	Luminous flux of the luminaire	717,0	lm
	Power	16,0	W
	Luminous efficacy	44,8	lm/w
	Luminous efficiency	6,6	%
	Distance between bollards	10,0	m
	Height of source	0,9	m
	Average Lux on ground level	5,24	lx
	Average Lux on face level	0,26	lx
	Number of luminaire per km	100	luminaires/km
	Watts per km	1600	W/km

Figure 68

Looking at Figure 68 were Dialux results are summed up and complemented with watts per km, CitySwan still offers a 56,25% less in power consumption. However the dimming possibilities that Eaton Invue can offer to reduce the power consumption, it has not been taken into account in the model. That possibility it would be part of the futur works of this project. However, the design, the rating between power consumption and light distribution and the high control possibilities make ARBOR as the elegible asset for the design. This bollard would be placed on the surrounding paths of the lakes in Utterslev Mose. In order to know when to use asymetric or symetric optics a conceptual catalogue has been done. (See Conceptual catalogue next page)

CONCEPTUAL CATALOGUE - Where to use symmetric and asymmetric?

SYMMETRIC

Double pathway with no difference in ground level or under 300mm*.

Distance: 10m
Consumption: 16W
Lumen: 717lm
Efficacy: 44,8lm/W
Efficiency: 6,6%
Per Km: 1600W/km




ASYMMETRIC

Single pathways and double pathways with a difference in ground level over 300mm.

Distance: 10m
Consumption: 16W
Lumen: 717lm
Efficacy: 44,8lm/W
Efficiency: 6,6%
Per Km: 1600W/km

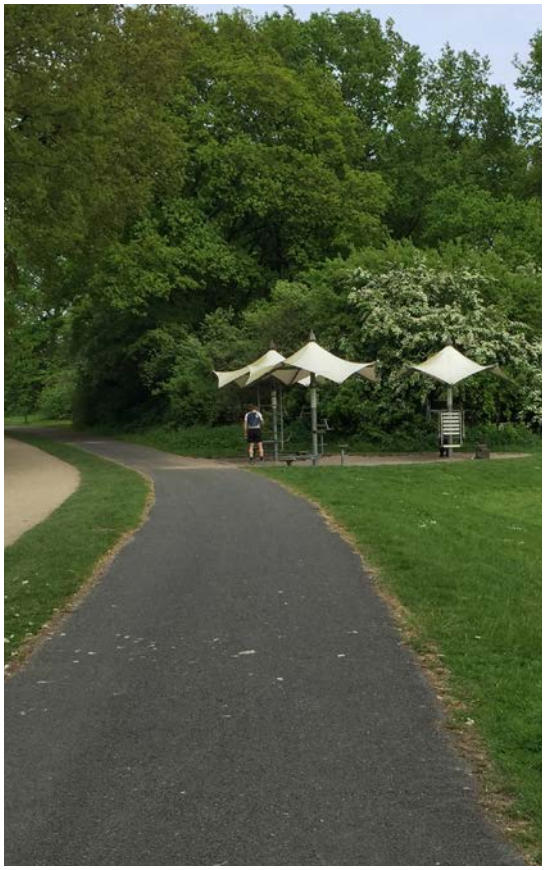



*The difference on ground level set up at 300mm is due measurements onside at difference paths in Uttersley Mose.

MAST Testing

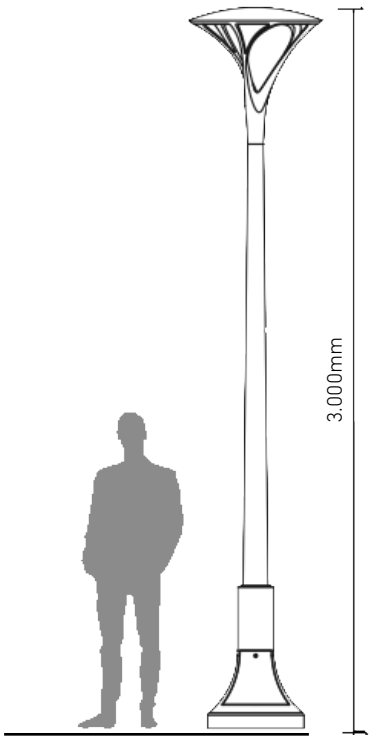
The luminaire for playgrounds and exercise areas is from EATON ARBOR's family design. This mast luminaire was tested in DIALUX to observe the illuminance that produces on ground level and to study what should be the distance between poles or how to distribute the luminaries in these areas.

First step is to observe the different playgournds and exercice zones where light is needed in order to find the most suitable way to lit each zone. The following images show the different Zones where mast luminares should be placed..The specifications of the product can be seen on Figure 69.next page.



Eaton Invue ARBOR Single pole

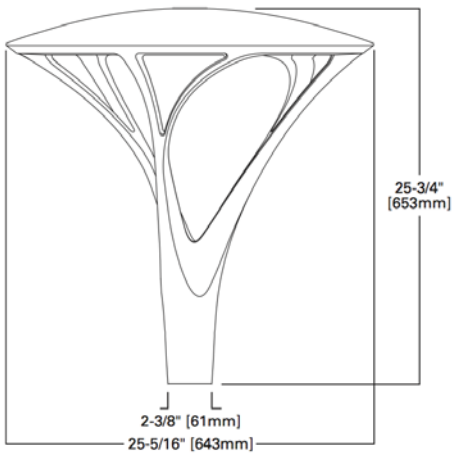
DIMENSIONS



POWER AND LUMENS

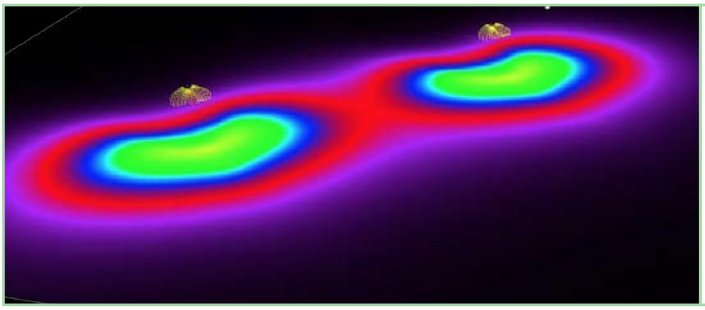
Lumen Package		B1	B2	B3	B4
Drive Current					
Power Wattage (Watts)		24W	48W	96W	99W
Input Current (mA) @ 120V		200	400	800	830
Input Current (mA) @ 208V		120	240	470	480
Input Current (mA) @ 240V		100	200	400	420
Input Current (mA) @ 277V		90	180	350	360
Power Wattage (Watts)		26W	53W	107W	108W
Input Current (mA) @ 347V		79	161	325	328
Input Current (mA) @ 480V		58	117	235	237
Optics					
Type II	Lumens	2,045	3,994	7,362	--
	BUG Rating	B1-U1-G1	B1-U2-G2	B3-U2-G3	--
Type III	Lumens	2,324	4,534	8,451	-
	BUG Rating	B1-U1-G1	B1-U2-G2	B2-U2-G3	--
Type IV	Lumens	2,408	4,691	8,740	--
	BUG Rating	B1-U1-G1	B1-U2-G2	B2-U2-G3	-
Type V	Lumens	2,311	4,529	8,511	9,464
	BUG Rating	B2-U1-G1	B3-U2-G2	B3-U2-G3	B3-U2-G3

DIMENSIONS

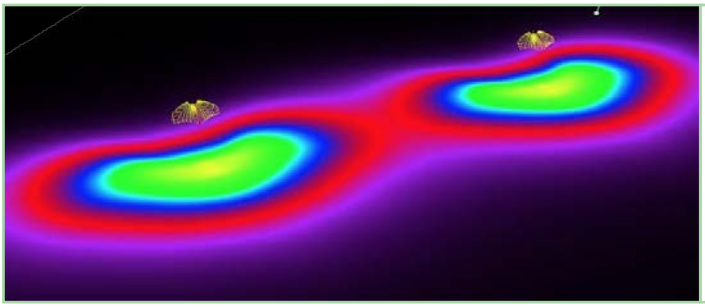


ARBOR Single Pole is a good asset to lit playground and exercise zones in order to complement the bollard lighting for Utterslev Mose. As the bollards luminaries, the single pole is equipped with wide range of control possibilities to minimized the power consumption. Comparing this luminaire with Philip Park and City-Swan-Basic studied in the analyses, Arbor is in second position with an efficiency of 13,4%, right-after CitySwan-Basic with 13,7%. Although CitySwan has a slightly higher efficiency, it is using 24W when Arbor gives similar illuminances by using 21W.
To reach at this conclusion several tests in Dialux was carried out to study how performs ARBOR Single pole in each of the optics possibilities. They can be seen on next page.

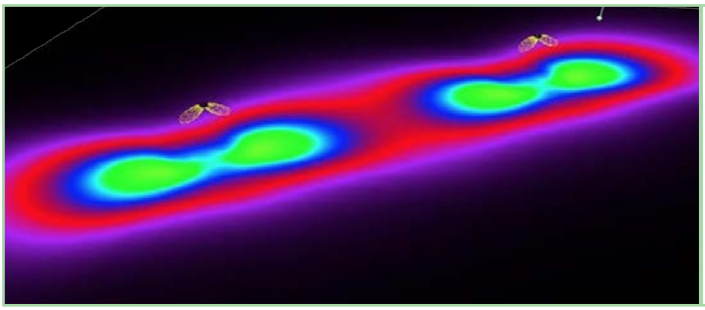
In order to choose the right optic DIALUX tests took place to observe illuminance distribution on ground level and to study which one would satisfy in a better way the users needs. Next images shown the 3Dmodel in false color of the most interesting cases that help to develop the second concept catalogue to guide how should be lit each of the areas by using this luminaire. (Concept catalogue for Single Pole can be seen on next page)
Luminaires are in a distance of 30meters.



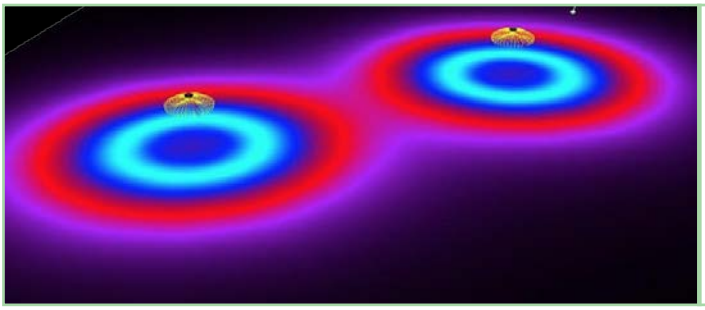
ARB-B1-LED -D1-T4-8030
L.Flux:2011lm
Wattage:24W
Efficacy: 83,8 lm/W
Efficiency: 12,2%



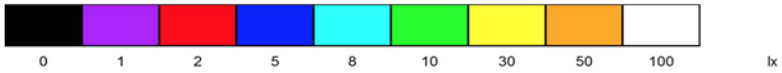
ARB-B1-LED -D1-T3-8030
L.Flux:1941lm
Wattage:24W
Efficacy: 80,9lm/w
Efficiency: 11,9%



ARB-B1-LED -D1-T2-8030
L.Flux:1708lm
Wattage:24W
Efficacy: 71,2 lm/w
Efficiency: 10,4%



ARB-B1-LED -D1-T5-8030
L.Flux:1930lm
Wattage:21W
Efficacy: 91,9lm/w
Efficiency: 13,4%



Optics TYPE II-III-IV

Always when is possible to avoid placing luminaires in the middle of a playground or exercise area, one of this types will be selected depending on the position and distribution of the activities zones.

Consumption:
21W
Lumen:
1930lm
Efficacy:
91,9 lm/W
Efficiency:
13,4%
*Per Km: 714 W/km




Optics TYPE -V

There is a preference in selecting the optic that adjust as much as possible the light distribution on the area where is the activity. The type V, will be use when light is required to be spread radially.

Consumption:
24W
Lumen:
1708-2011lm
Efficacy:
71,2-83,8lm/W
Efficiency:
10,5- 12,3%
*Per Km: 816 W




*The calculation of power consumption per Km, has been done in order to have the possibility to compare with the other luminares studied in the analyses when they are arranged in a line.

6.5 EVALUATION

The whole strategy used in the lighting design for Utterslev Mose has been in relation to be energy efficient at the same time that can cover users needs and minimize the impact in wildlife depending on which type of luminare,optics and disposition is used. Next table shows the total power consumption that would be used in Utterselv Mose. On next page it will be compared with Fælledparken and Søndermakren.

The total amount of luminaries that would be need for the design are:

BOLLARDS

Total Path Km: 8,7km
Total number of Bollards: 870 luminaries
Lumen per luminaire: 717,0 lm
Power per luminaire: 16 W
Efficiency: 6,6 %

Total watts: 13.920 W (from the total would need to be applied the reduction on the control possibilities which it would decrease the amount of the power consumption)

MAST

Total number of mast: 7
Power per luminaire: 21-24W
Lumen per luminaire: 1708-2011lm
Efficiency: 10,5-13,4%

Total watts: 147W (from the total would be need to be apply the reduction on the control possibilities which it would decrease the amount of the power consumption)

The total amount of power consumption used only for luminaries in the design would be: **14.067 W** where it should be subtracted the power that could be reduce by the control possibilities.

In order to be able to evaluate and compare the efficiency between green areas, it has been studied the amount of watts per kilometre that each type of luminaire consumes, since each green area has a different amount of square meters and paths lit. Moreover, as in all cases it is used bollards and mast, it has been studied W/km in both types of luminaries, even though the Mast luminaries are occasionally placed.
Therefore, when comparing the total consumption of each green area, next table shows the consumption of each type per km and the total consumption of the park.

FÆLLEDPARKEN

Total number of Bollards: 224 luminaries
Lumen per luminaire: 617,0 lm
Power per luminaire: 27W

Per KM: 1.809 W/km

Total number of Mast: 45 luminaries
Lumen per luminaire 3614lm
Power per luminaire:58W

Per Km: 2088,0 W/km

Total power: 8.658 W used in Fælledparken.
Total km lit: 3'5km.
Total:2473,7w/km
Efficiency: 5,01%

SØNDERMARKEN

Total number of Bollards: 121 luminaries
Lumen per luminaire: 380 lm
Power per luminaire: 7W

Per KM: 469 W/km

Total number of Mast: 26 luminaries
Lumen per luminaire 2260 lm
Power per luminaire:24W

Per Km: 792 W/km

Total power: 1.471 W used in Søndermarken.
Total km lit: 3,5km.
Total: 420 W/km
Efficiency: 10,4%

UTTERSLEV MOSE

Total number of Bollards: 870 luminaries
Lumen per luminaire: 717,0 lm
Power per luminaire: 16W

Per KM: 1.600 W/km

Total number of Mast: 7 luminaries
Lumen per luminaire 3614lm
Power per luminaire: 21W

Per Km: 714,0 W/km

Total power:14.067 W used in Utterslev Mose.
Total km lit: 9km
Total: 1.563 W/km
Efficiency: 6,8%

Efficiency

Looking at the table on the previous page, It is possible to evaluate the lighting design of Utterslev Mose with higher efficiency than Fælledparken, but still 3,6% less efficient than Søndermarken. Although, It is important to mention that the calculations for Utterslev Mose has not taken into account the control possibilities (dimming, sensors,..etc.), which will make decrease the wattage percentage of the lighting system.

Users' needs

Observing the lighting distribution that each system is offering to users, Søndermarken will be the least efficient its light distribution gather higher illuminance values on the first meters closer to luminaries and It leaves darker spaces under 1 lux in between the two bollards or mast. Moreover this distribution of the illuminances produce a high contrast that makes it more difficult for the visual adaptation process. On the other hand , ERCO luminaire and Philips Park used in Fælledparken, have a more even distribution but the result it is still less homogeneous than the one that Utterslev Mose is offering. Reducing the distance to 10meters between the bollards allow the system to cover the whole path without dark spaces and due the high efficency of the luminaries the overall system is still using less Watts per kilometer than in Fælledparken.

Wildlife

Last but not least, Utterslev Mose lighting system has consider wildlife by using bollars luminaries on pathways reducing like this the aerial impact of mast luminaries. Moreover, it has been illuminated only the main paths in order to leave dark areas for wildlife. Even tough upwords back-lighting in Søndermarken offers a safty feeling to users when walking in the park, in Utterslev Mose this technique has not been used to avoid the aerial impact but still offer some information of the surrounding thanks to the light distribution on the ground level of the asymmetric ARBOR bollards, which slightly illuminate the closer meters to the pathway.

7. CONCLUSION

"How to design a lighting system for Utterslev Mose to improve the lighting efficiency while covering citizens needs and considering wildlife? "

In order to design a lighting system for Utterslev Mose, a previous analyses of the current lighting in green areas had to be done. Carrying out a good analyses can become essential to design the right lighting system, reason why the process started by gather information to observe and to study how green areas are lit.

"When designing something for people is essential to listen people"

The data collection allow to observe the different green areas in Copenhagen and Frederiksberg municipalities. Starting from a photographic report and a survey it gave the first inputs about how users experience each area and what people think, like or would prefer to have in it. The survey gave an impression of the Danish citizens as being engaged with nature. They respect it and appreciate it. They like to spend time in it and they want more variety of nature right next to their door. They ask and municipality give. Copenhageners have a high amount of parks inside the city and that is because municipality always listen people to cover their needs. For the same principal this projects took in consideration people's voice.

"Observe the space, take measurements and make it better"

Without technical measurements It is impossible to prove or compare the efficiency of the different green areas. For that, lux measurements were necessary in order to study the illuminance levels in each area. Moreover, the study give the chance to observe how users needs are satisfied and how is the relation between the lighting system and nature.

Considering that the analysis is a collector of tools and tips for your design. From the analysis of this project It was possible to collect that the usage of two type of luminaries in green areas, can give a good combination of efficiency , user's needs and wildlife. Using bollards the light distribution is focused mainly on the pathway to cover users needs at the same time that is minimizing the impact in wildlife by reducing the aerial pollution.

Having tools to play with, the design process was simplified. It studied what happen if using the same material that It is already in use , the situation can be improved just changeing the technique. It studied and test new materials in the market and it permit to give as a result a lighting design able to find a good balance between the three parameters of efficiency, users and wildlife.

As mention in the evaluation, the efficiency obtain from the Utterslev Mose lighting design is 6,8%. It is less efficient than Søndermarken, but It is better in light distribution covering users needs. This , as everything, is a matter of choice and preferences. There are parameters and all depends on what you want to collect. Then, that parameter has a more important roll in the design to achieve the goal. However, in this project the goal was mainly

8. FUTURE WORKS

This section mention possible works that would help to improve the Utterslev Mose lighting design that has been presented in this project.

As mentioned during the design phase, the luminaries used , ARBOR bollard and single pole, offer a wide range of control possibilities to improve the lighting system and reduce the energy consumption. A relevant task to improve the design of this project would be to test all these possibilities and to observe how each of the changes affect the consumption.

Additionally and related to the intelligent lighting, programming the codes to define the selection of colours to study how well this colour transitions performs is another future task.

Finally, the budget. There was an attempt in gathering the information about cost of the luminaries, since it is not specified on the manufacture website. Unfortunately, there was no answer about any approximation cost of each type of luminaries and It was impossible to carry out any type of estimation.

9. ANNEX

9.1.SURVEY QUESTIONNAIRE

1. What is your age?
2. About how often do you go to the park?
3. When going to the park, which is your usual activity?
4. Around what time do you usually go to the park?
5. How well do you think are the paths lit in the park?
6. How safe do you feel when you visit the park when there is no daylight?
7. Do you know that there is a park called Søndermarken in Frederiksberg that offers a possibility of using an interactive lighting system to complete an specific route? Have you ever used it and how often?
8. When you think about the interactive lighting system, do you think of it as something people is happy about it or not?
9. If you had the possibility to improve something of Fælledparken what it would be?
10. Observations:

9.2 REFERENCES

[1] - Survey - https://da.surveymonkey.com
[2] - Copenhagen master plan
http://data.kk.dk/dataset/025cd497-a6d2-47ee-ab6d-0b7df5e02bc9/resource/c826ce6a-1c76-4a73-bd2d-fd7719d8d011/download/belysningsmasterplan-kobenhavn-del-1-fornyelsesprojektet.pdf
[3] -http://www.dn.dk/Default.aspx?ID=30777

9.3 LINKS

https://da.wikipedia.org/wiki/Fælledparken
http://www.dn.dk/Default.aspx?ID=30785
https://en.wikipedia.org/wiki/Human_height
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http://www.christianshavnernet.dk/Christianshavn/Havnefronten/Oerestad/
http://www.dn.dk/Files/Filer/Oplev_naturen/www_fredninger_dk/oestre_anlaeg_kbh.pdf
http://www.dn.dk/Default.aspx?ID=30777
http://slks.dk/slotte-ejendomme-og-haver/skal-slettes/drift-af-kulturejendomme/drift/slotshaver/frederiksberg-have-og-soendermarken/planlaeg-besoeg/
http://www.cisternerne.dk/om-cisternerne/sondermarken.html
http://ghb-landskab.dk/en/projects/life-and-light-in-soendermarken#mere
http://slks.dk/slotte-ejendomme-og-haver/projekter/afsluttede-projekter/projekt-liv-og-lys-i-soendermarken/
http://www.priess.dk/master-arkitekttegnet/cityswan/cityswan-basic
http://download.p4c.philips.com/lfb/f/fp-910502610226/fp-910502610226_pgl_en_aa_001.pdf
http://download.p4c.philips.com/lfb/c/comf-1198/comf-1198_pss_en_aa_001.pdf
http://www.nheolis.de/pdf/343-021_Final%20Report_Development%20CO2%20neutral%20hybrid%20street%20lighting.pdf
http://www.boston.com/weather/weather-wisdom/2014/06/20/summer_begins_solstice_occurs
https://www.google.dk/imgres?imgurl=http%3A%2F%2Fi.kinja-img.com%2Fgawker-media%2Fimage%2Fupload%2Ftpexxxero6zwp6tc9tmr.jpg&imgrefurl=http%3A%2F%2Fio9.gizmodo.com%2Fheres-what-happens-to-the-earth-during-summer-solstice-1593675122&docid=k3rXT7C84V4U1M&tbnid=SH-rA9vNpsufeM%3A&w=700&h=541&client=safari&bih=680&biw=1240&ved=0ahUKEwj504G6xc3MAhXFfywKHZRbDH44ZBAzCBwoGTAZ&iact=mrc&uact=8
http://www.windows2universe.org/the_universe/uts/winter.html
http://www.prettyyourworld.com/colortheory.html
http://www.fredninger.dk/dnressources/Turkort_Utterslev_Mose.pdf
http://www.fredninger.dk/fredning/utterslev-mose/
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