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Public lighting for Hyldebjerg

Zoltán Tasnádi





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Aalborg University Copenhagen

Frederikskaj 12,

DK-2450 Copenhagen SV

Semester Coordinator:

Secretary:

Supervisor(s):

Georgios Triantafyllidis – supervisor

Andrei-Ducu Predescu – co-supervisor

Author:

Zoltán Tasnádi

Abstract:

This thesis, has been written in collaboration with Lighting Metropolis and its partners. The primer project goal was to create an interactive and innovative lighting design for HyldeSPAeldet, a neighbourhood of Albertslund, and to facilitate outdoor social activities. Based on participant observations and in agreement with the collaborators the following problem statement was developed:

“Public spaces in HyldeSPAeldet are scarcely used in the night time by the local residents in lack of *appropriate* lighting”

Appropriate outdoor lighting was interpreted as aesthetically pleasing, interesting and enticing, on top of being functional. Research article and study results were collected regarding outdoor lighting parameters and human reactions to it, to find the factors that make a lighting setup attractive, appropriate. The findings have been merged together to utilise their maximum potential, and been translated to the specific case of HyldeSPAeldet, after a thorough analysis of the site. Street structure, architecture, current lighting situations, users, user behaviour, user feedback and local characteristics has been taken into consideration in the design. As a final goal this design proposal aimed to establish a new platform that generates outdoor activity and social interaction. This purpose is expected to be achieved by a delicate combination of a customizable private and public lighting

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Introduction

This report has been written in the collaboration of Aalborg University Copenhagen, Albertslund municipality, Lighting Metropolis and DONG energy.

Albertslund is a renowned settlement in the agglomeration of Copenhagen of its well-planned urban structure, great green spaces and sustainability related innovations, initiations and developments. Car traffic and non-motorized transportation are separated from the first development plans in the 1940's, thus promoting alternative, car free and active methods and at the same time providing a more efficient transportation system. The 60% green environment proportion of the total dimension of Albertslund also praises its urban development plans, and highly contributes to a healthy and sustainable society and city. (Albertslund Kommune, 2017)

Furthermore, Albertslund is home of an industry park, operates a “living lighting lab” on the streets together with DOLL, and is a member of Lighting Metropolis and Gate 21. The latter organization is dealing with green transition, intelligent local climate and energy solutions in greater Copenhagen. Lighting Metropolis, being coordinated by Gate 21, aims to build a strong cooperation system among universities, official authorities, lighting professionals, manufacturers and other related service companies in order to synthesise, utilise and transform the gathered knowledge into innovative and sustainable lighting infrastructure developments. The organization emphasises the triple helix model, which involves the government, the industry and the academic institutions and knowledge, in order to achieve innovations. Projects are focused on designing ground breaking and human centred lighting. The European Union's European Regional Development Fund (ERDF) funds both mentioned organizations and besides Albertslund, other members are Copenhagen, Roskilde, Frederikssund, Kalundborg, Egedal in Denmark and Malmö, Lund and Helsingborg in Sweden.

While writing this paper Albertslund has been upgrading its street lighting system due to obsolescence. As the city's municipality is a member of Lighting Metropolis, it was considered relevant and beneficial to establish a project together in order to gain knowledge about lighting, fixtures and the applicability of the newest technologies. Therefore, the environmental department of Albertslund selected a test area with the most unique features and challenges, namely Hyldebjerg. The guiding principle was to choose a specific site with potentials for ground breaking, innovative design solutions and create a case study, which findings can be applied subsequently to Albertslund's development plans. Hyldebjerg has a complex lighting system with more than 400

luminaires in less than one km². There are multiple types of fixtures and the spatial and street structure also makes the area unordinary.

Another key aspect was to gain knowledge about user involvement into design process, especially into a relatively technical one, and Albertslund considered this project as an experiment in this topic. Hyldebjerg has participated other projects before and this was an additional argument to choose that neighbourhood again.

Last but not least promoting and extending outdoor space use in the dark hours was an initial project goal, since in the Scandinavian countries' daytime is short during the winter, thus, use of outdoor public spaces is drastically reduced.

DONG energy on behalf of the industry has joined the project first and foremost because it's the responsible party for maintenance of Hyldebjerg's street lights and secondly it is a member of Gate 21 and Lighting Metropolis as well. By representing the academic knowledge component in the triple helix model, Aalborg University Copenhagen had the opportunity to be an integral part of this Lighting Metropolis project in Hyldebjerg.

As a student of the above-mentioned institution, the author of this paper found the project goals interesting and related to his landscape architecture educational background. The project's scale is considerably large, and designing public lighting for a unified suburban community with direct access to green spaces has a significant sociological effect, and affects the use of outdoor spaces as well. Therefore this lighting refurbishment project has strong urban and landscape design aspects too.

The author provided effective contributions throughout the project in site visits, data gathering, analysis, design process, user involvement and in project management as well. The final goal of this report is to deliver an innovative and interactive lighting design proposal focused on human centeredness with emphasis on the local context.

Pre Analysis

In the following chapter, the project area will be investigated and introduced in order to get a comprehensive image of Hyldebjerg and a basis for the subsequent steps in the design process. Information was gathered in three fields: anthropology, architecture / landscape architecture and lighting.

General introduction of the site

Hyldebjerg is part of Albertslund, a town in the Copenhagen metropolitan area located 15km from the Danish capital, with 27698 citizens (Albertslund Kommune, 2017). The ancient villages Risby, Vridsløselille, Herstedvester and Herstedøster have merged, and they currently exist as neighbourhoods of Albertslund, such as Hyldebjerg. Previously there had been an agricultural field around the middle of Albertslund until 1974 when the construction of a new residential area started, based on the plans of architect Ole Asbjørn Birch and landscape architect Andreas Bruun.



Figure 1. Albertslund, Google maps 2017

The total dimension of Hyldebjerg is somewhat less than one km². This relatively small area accommodates 383 apartments and 663 residents. As the pie chart shows in Figure 2, the 0-18 years old group is approximately 23% of the local nation. Based on „Aldersfordeling” – age distribution, the 0-30 age category comprises some 37% in total, so more than one third of the population might be considered as young. The age pyramid shows a developed country’s pattern with high life expectancy, more elderly and less new born. Even though, the proportion of children in the neighbourhood is slightly higher than the Danish national average (*populationpyramid.net, 2017*).

In addition to the relatively positive demographic data of Hyldebjerg, the neighbourhood is exceptional in terms of its community and local initiatives as well. Hyldebjerg has started to integrate urban ecology in 1989 into their present suburb. The first initiation was a chicken coop on public land, managed by 10 families who provided eggs for the entire neighbourhood. This project proved to be worthwhile and popular especially among children, and many more chicken farms were established subsequently throughout Albertslund. The next

project was a recycling depot and today all household waste goes to composting bins or to chickens. Later a group of people established a vegetable garden on a rented 2.5-hectare site and others began to manage natural playgrounds. All these activities are now part of living in Hyldespjældet, and made the local community very strong and the neighbourhood outstanding, since almost every resident is a member one of the groups. (Newman & Kenworthy, 1999)

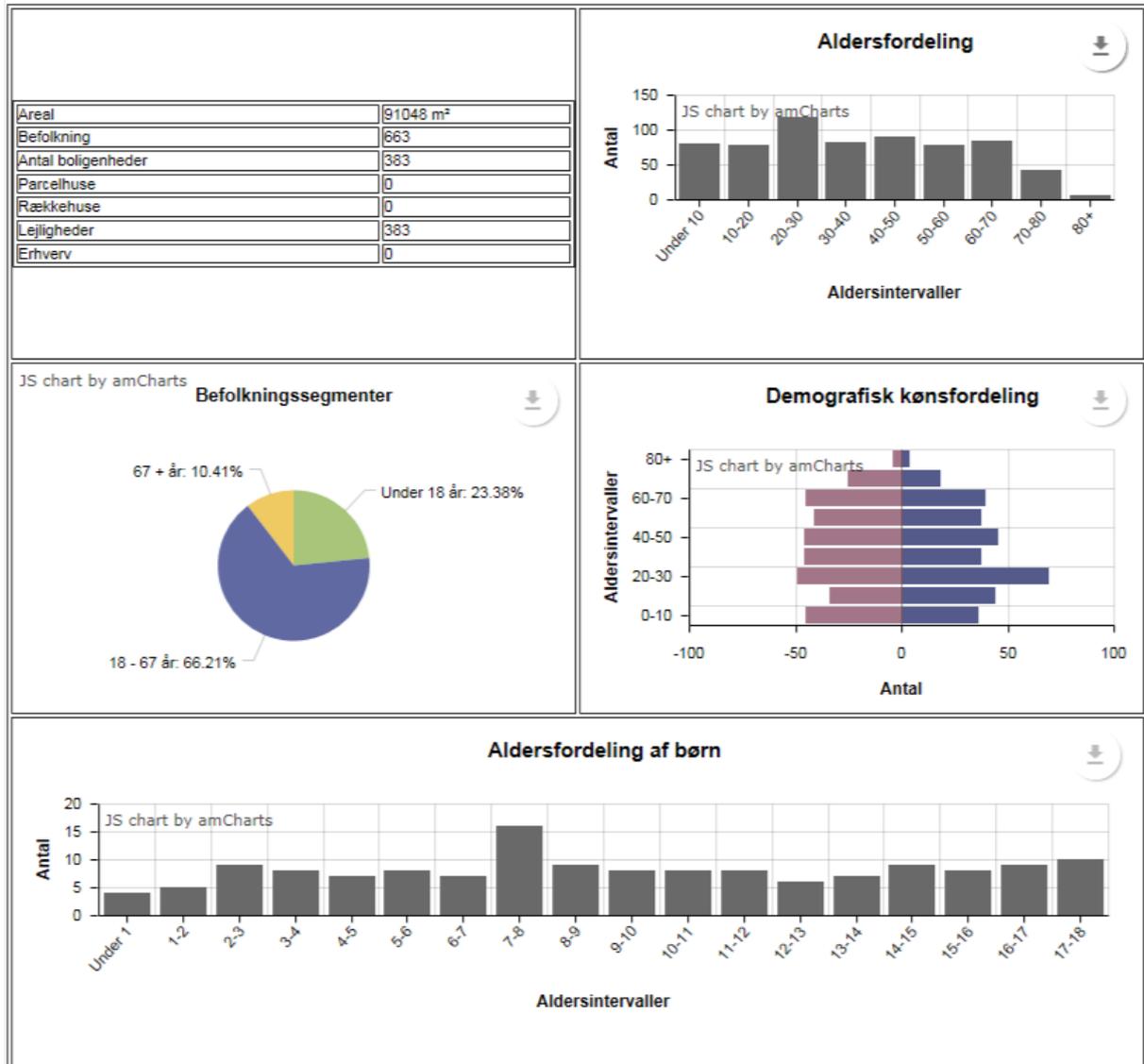


Figure 2. Demographical data of Albertslund - Albertslund municipality

Another relatively unique aspect of Hyldespjældet is that the neighbourhood's public affairs are handled by a housing management company called BO-VEST. Besides that, it is responsible for the general physical maintenance of apartments, streets, and public spaces it provides services internet and TV services as well. Such maintenance and development system is common for smaller building blocks, but in Hyldespjældet's case, it was realized in a larger scale. This maintenance structure also contributes to the strengthening of the local coherence and uniformity.

Spatial structure

The 1970's were the golden age for suburbs in Europe and also overseas. Copenhagen even forewent this general tendency by establishing comprehensive urban development plans from the end of the 1940's. Accordingly, Albertslund as a suburb of Copenhagen had been affected by the development strategies, and started to grow drastically in population from the 1960's. Hyldebjergdal correspondingly inherited from the era's and Albertslund's characteristics, which will be unfolded in the followings.

Exploration of Hyldebjergdal's spatial structure was begun by investigating Google maps territorial and satellite view. Multiple site visits followed up the online research to form a comprehensive image and to collect empirical input as well.

Transportation and streets

As it has been mentioned before, Hyldebjergdal is situated in the middle of Albertslund, and inherited similar accessibilities as the city itself, with the difference that cars are not just simply separated from the active means of transportation there, but also excluded from the territory of the neighbourhood. Parking lots are located along the southern and eastern borders but further entrance is only allowed on foot, by bicycle or with other small-wheeled vehicles (skateboard, push scooter ... etc.). An evaluation of Danish urban ecology projects found that Hyldebjergdal has 30% less car ownership than a similar "control" middle suburb, 50% lower vehicle travelled per year and 15% fewer car trips. In fact, 74% of the households in Hyldebjergdal live in a "car-free" way. (Scheurer, 1998b; Newman & Kenworthy, 1999).

Regarding transportation within Hyldebjergdal, there are four types of streets (*Figure 3*). Main streets, which are 6.5 - 7.5 meters wide, side streets and sub side streets with 5 and 3 meters width, and the roughly 1 meter wide backyard lanes. A divergent main street line connects Hyldebjergdal to the neighbouring regions. The line going southeast (marked with black) leads directly to the city centre, to the transportation hub, which connects Albertslund to the surrounding settlements. Due to this divergent street structure, there are numerous possible routes within Hyldebjergdal to get from A to B. According to the results of a conducted questionnaire of transportation routes and space use, local residents tend to alter their way through the neighbourhood and there is no "most

favoured” or “most used” alternative, thus, route hierarchy is fairly even. However, there are functions and facilities that attracts more movement.

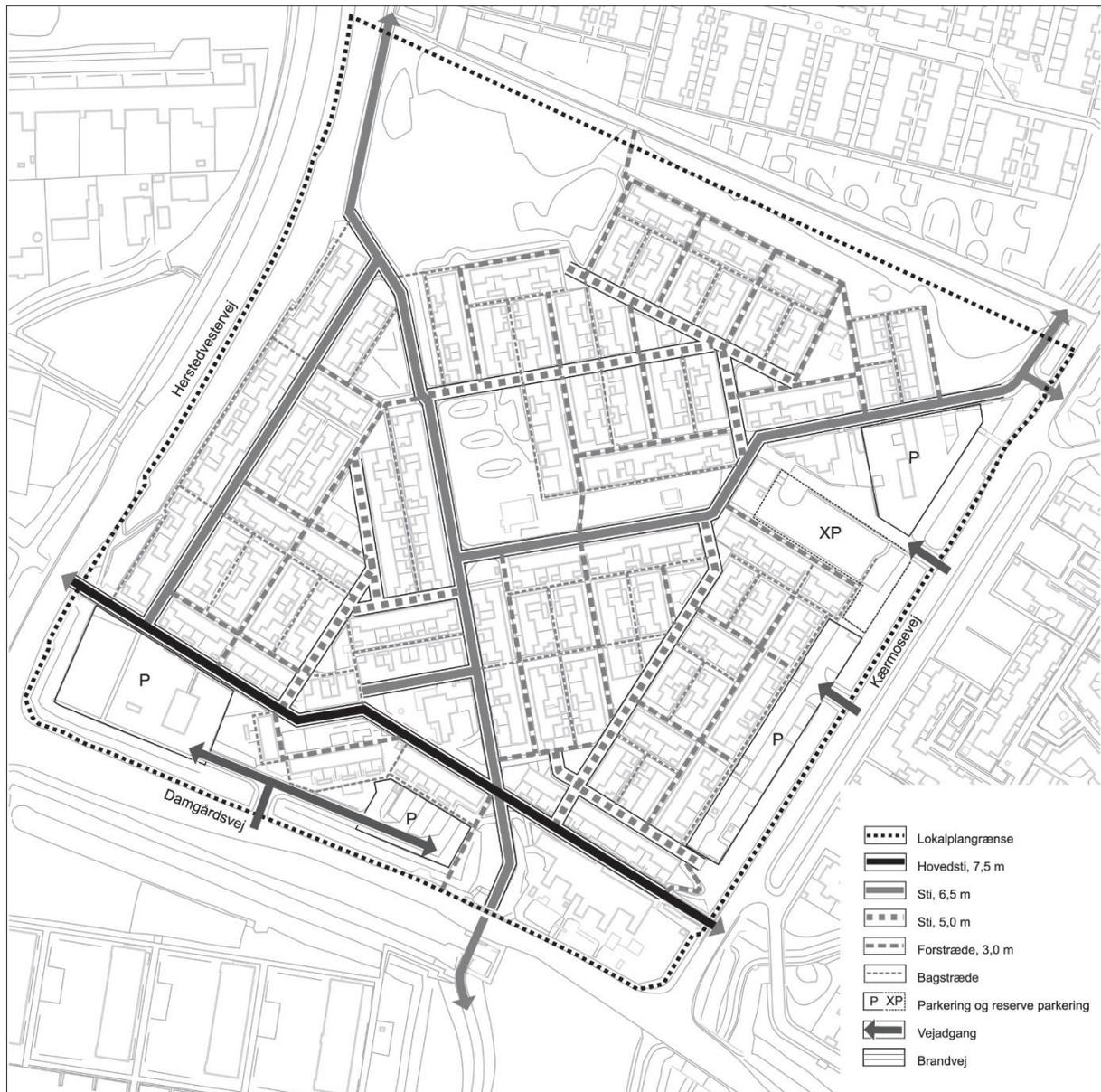


Figure 3. Albertslund Kommune, Lokalplan no. 15.1 Hyldebjerg

One of the reasons for the alternating route preference lies in Hyldebjerg’s unique characteristic that the neighbourhood functions as an outdoor exhibition of sculptors. Throughout the public open spaces, 44 sculptures are being exhibited. This initiation is beneficial for the sculptors and the neighbourhood as well. Sculptors do not have to pay any kind of exhibition or storage fee and this way Hyldebjerg have another artistic and cultural layer that only adds value to the environment and to the local identity. Some of those sculptures have even been donated to Hyldebjerg, thus they constitute permanent pieces of the exhibition.

Outdoor spaces

Hyldebjerg is bordered by narrow vegetation lanes from all sides, see Figure 4, but these green areas do not support any kind of active use due to their denseness. By contrast, the majority of outdoor spaces, if the dimensions of street surfaces are not taken into account, are actually green spaces or comprise green elements, and those elements facilitate recreational functions. These spaces are noted with light green in Figure 4. Solid surface covered spaces are marked with light blue and regarding proportions it is visible that green surfaces are dominant. Therefore, it can be stated that natural areas and vegetation in general are essential parts of the local environment, insomuch that gardening, eco-farming, and other previously mentioned environmental friendly and sustainability related activities are indispensable trademarks of Hyldebjerg.



Figure 4. Space structure

As several studies found, green elements or green environment has significant beneficial effects on recovery, mental and physical health, general wellbeing, and

in addition, affects social behaviour and interactions in a positive way. (Ulrich, 1991; Kuo, et al., 1998; Groenewegen et al., 2006) These results are confirmed to the extent in the case of Hyldebjerg, that the community's strength is significantly based on activities involving nature and outdoor green spaces.

Space hierarchy

Evaluating outdoor spaces from a dimensional aspect, a fragmented structure was observed throughout the neighbourhood. The reason for the existence of smaller scattered spots is mainly the divergent and hierarchical street structure.

By contrast, as Figure 4 indicates, there is a larger green surface concatenation spreading out from the north-western corner to the eastern border. The northern end of the concatenation begins with a large greenery with a slight slope. That space is equipped with picnic benches, tables, fireplaces, football gates and even kitchen gardens take place in the corner of this area, and therefore it accommodates a wide range of outdoor activities. A lookout tower has been built there as well in the past years, but due to technical problems, it is out of order. This northern area connects with a narrow green lane to the centric "L" shaped green space in the heart of the neighbourhood, which functions as a structural focal point, a green junction, a natural meeting zone. As an additional function, that space comprises a playground with a relatively large wooden "Harry Potter" castle, which creates a unique atmosphere. The following jointing greenery connects the central area to the peripheral parking lots, and to the road entrance on the eastern side, see Figure 4.

This discussed concatenation is the one on top of the dimensional hierarchy of outdoor spaces, however, the situation is nuanced by the functional and usage hierarchy. To map latter two, participant observation (*Spradley, 1980*), and short informal street interviews (*Yin, 2011*) were conducted.

As a result, the author of this paper found that main outdoor activities are including but not limited to bicycling, strolling, walking with pets, going out to public spaces, going to the playgrounds.

Spaces and their functions are indicated in Figure 4. As it can be seen, there are three functional focus points. Two of them are the previously mentioned green spaces, the northern and the central one, the third is the café area in block "Storetorv". The latter provides the highest function density but with mainly indoor functions: café, gym, laundry, grocery, playground. There, the most important is the café itself, which functions as a locally operated restaurant every Tuesday and Thursday night. According to the interviewed residents, local people

tend to visit these events and the café is an important social meeting point of the community.

In conclusion, and based on the above-mentioned research results, the most used and visited outdoor area is doubtless the central “L” shaped green space and its playground. This area gathers multiple recreational functions together, and as its placement also entails, it operates as the main public space of the neighbourhood. In the case of smaller, fragmented outdoor spaces, there is no frequent attendance or significant period of stay.

Architecture

According to the architectural style of the 70's era, buildings in Hyldebjerg show mixed traits of Bauhaus and Art Deco. The first thing that meets the eye of the observer are the colours. Bourdon (at some points blue) concrete panel walls with rough plaster cover are paired with pastel blue, yellow, green, and red painted wooden window frames and entrance doors. Besides the applied colours, simplicity, dominant square shapes, strong edges, and relatively low building heights (maximum 2 stories) and flat roofs typify the local architecture. Walls are made of premade concrete elements, therefore between each element there is an approximately 1.5 - 2 cm assembly gap. This feature further emphasises the cubical appearance of the buildings. To ease this strict style, flat roof angles vary throughout Hyldebjerg, even in building blocks. (Figure 5)



Figure 5. Hyldebjerg's architecture

As a relatively new, eco-friendly and sustainability related initiation in Hyldebjerg, particular roofs has been changed to green roofs. This architectural solution creates additional green surfaces, therefore increases biodiversity. Furthermore, contributes to vegetation's mitigation effects on urban development caused problems. By moderating climate, conserving energy, reducing carbon dioxide improving air and water quality and controlling rainwater runoff and flooding vegetation provides solution to many problems of modern settlements (Dwyer et al., 1992; Párkányi, 2007). Neither Hyldebjerg nor in larger scale Albertslund are in lack of green spaces, but implementing green roofs have more direct and practical benefits as well on our everyday life. First of all green roofs' vegetation are widely variable in terms of species, colours and habitus, thus gives the designer a great tool create an aesthetically pleasing composition which fits the local context. On the other hand, green roofs are great insulation systems, which keeps the house cool in the summer and warm in the winter.

Further exceeding in energy efficiency and sustainability, as an experimental project, solar panels has been installed to some rooftops, along with green roofs. In the near future BO-VEST plans to refurbish all the buildings in Hyldebjerg with a more up to date insulating system on the walls, green roofs and solar panels, to achieve a minimum energy consumption and high efficiency. This means a drastic change in façade appearance and due to the approximately 50cm increase in the width of the insulating layers, streets' airiness especially in the ones between two building blocks will decrease significantly.

Lighting

Out of 65, Hyldebjerg is one of those neighbourhoods, which have the most lighting fixtures per territorial size. According to the DONG Energy database, there are more than 470 luminaires out there. The majority of them are maintained by DONG Energy. Those are the approximately 360 wall mounted façade lights, marked with purple dots in Figure 5, and there are around 110 street and wall mounted lamps maintained by Albertslund municipality, marked with yellow dots. Theoretically, this would imply appropriate and satisfying lighting conditions, but as it will be unfolded in the followings, the case is not that simple.

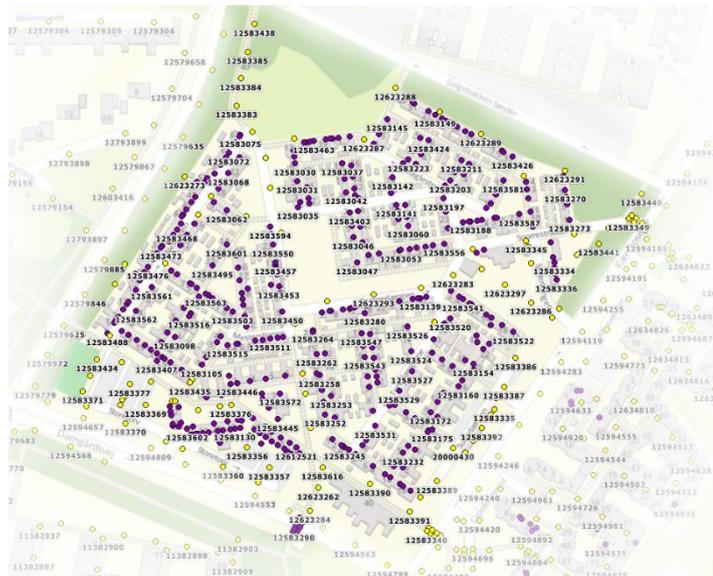


Figure 6. Light points of Hyldebjerg, DONG Energy

Field observations and measurements have been conducted in order to explore the current state of lighting. First the DONG energy database, and another digital documentation of the luminaires from Albertslund municipality were compared to real life situations in terms of fixture placement. All the purple marked fixtures were at their indicated place, functioning. Nevertheless, the state of the yellow marked streetlights were not that problem free. There were significant deviations from the online database, some of the luminaires were missing, placed differently or worked faulty at certain points. These differences were noted and located by the author of this paper to provide a basis for a subsequent refurbishment.

Since the DONG Energy database contained light source information regarding only the purple dot indicated luminaires, and there was no information about the municipality maintained lamps, further investigation was required. These investigations aimed to test the database's validity, to explore technical information about the fixtures and to get a comprehensive image of current lighting conditions and illumination levels.

For illuminance measurements, a Hagner EC1 lux meter was used. The device was carried around in the streets, approximately 10 centimetres from the ground, and values were continuously read from it and averaged for every distinct street.

Main streets are equipped with lampposts and all the apartment entrances have a wall mounted façade luminaire. In smaller streets, latter fluorescent lamps are the only light sources. (Figure 7). The mean illuminance value for the main roads is ~ 2 lux. In side streets, where there are two lines of facades facing each other, this value ~1 lux. In streets or paths where there is façade lighting only on one side, illumination is less than 1 lux. Backyard lanes are not illuminated at all since there are no light sources there.



Figure 7. Spectral Distribution of street lamps and entrance lamps

The different light sources were measured and compared with a spectrometer (AsenseTek alp-01). As the green curve indicates in the diagram in Figure 7 the new compact fluorescent bulb has significantly more radiation in the lower wavelength spectrum, and has a higher peak at 540 nm. It means its light contains more violet, blue and green colours, and that results in a more bluish, cooler, white light. As the CCT value shows, there is some 500-kelvin colour temperature difference between the old and the new bulbs. This deviation does not affect the colour rendering index (CRI), which is the same for both bulbs, but is very significant in colour quality scale (CQS) and in gamut area index (GAI). The latter two are additional colour rendering measurement methods addressing the shortcomings of CRI. (www.lrc.rpi.edu)

As a conclusion, both light sources are adequate to fulfil their purpose, but their deviation in appearance is fairly visible even for the non-professional eyes and might be disturbing. (Figure 8).

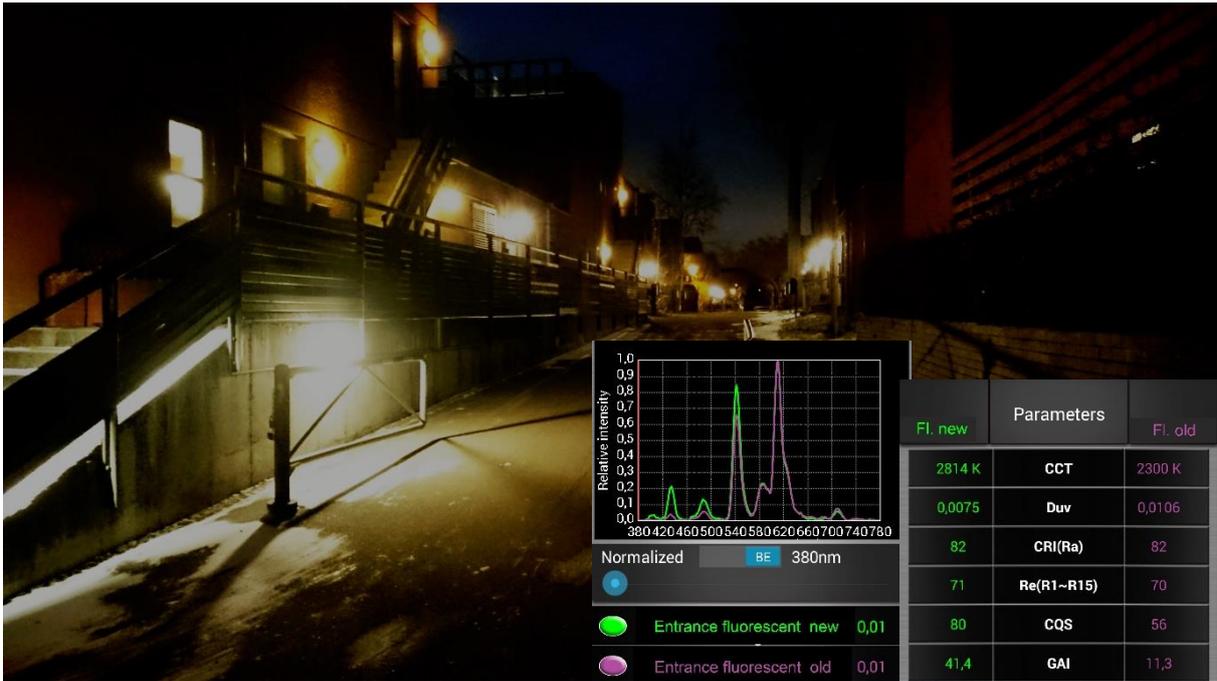


Figure 8. Spectral Distribution of different CFL entrance luminaires

Albertslund municipality's lamps are in the main roads, the peripheral parking lots, the tunnels, the bordering streets of Hyldebjerg and in parking sheds. The DONG Energy online database has no information on their light source type, therefore personal observations and technical measurements were conducted. As a result three different light source types were found, high-pressure sodium (HPS), LED and compact fluorescent (CFL). Sodium lamps are the oldest, the original ones and at random places they had been changed to compact fluorescent or more up to date LED. There are even two types of LED sources, one of them is warm the other is cool white. The spectral power distribution of the four different street lamps can be seen in Figure 9. From left to right: Cool white LED, warm white LED, HPS and compact fluorescent.

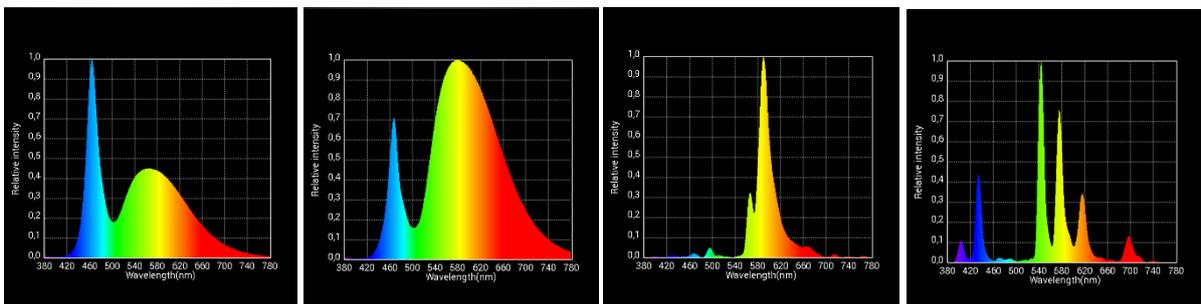


Figure 9. Spectral distribution of the CW LED, WW LED, HPS, CFL light sources

Figure 9 compares the two most different lights, the cool white LED and the orange HPS. These two were existing right beside each other at the date of the observations, and as the values and curves indicate, the visible difference is outstanding.

The 5815 kelvin bluish white beside the 1804 kelvin, a colour temperature of a candle, is prominent. Deviations resulted in colour rendering and level of visual disturbance as well, see Figure 10.

Residents already blocked one of the cool white LED lamps because with a much higher lumen output and a crispy white colour it causes significant glare issues. While the LED-s illumination right under the lamp was 57 lux, this value in the case of the HPS was only 7 lux in average. This results a very high and disturbing contrast. (Figure 10).



Figure 10. HPS street lamp, CFL entrance lamps, Cool white LED street lamp

As it has been mentioned before, the average illuminance levels in Hyldespjældet are under 2 lux. In backyard lanes and along the bordering green lines around the neighbourhood this value is even lower, close to zero, thus the randomly placed LED fixtures' great brightness is even more accentual.

Pre-Analysis conclusion

Being built in the suburbanization era as a neighbourhood of a suburb, Hyldespjældet inherited characteristics from multiple sources. First of all, even this relatively small area can be interpreted as an individual suburb of Albertslund, based on its features that are: no / very few public institutions, very few services, large green space dimensions, private gardens and high commuting rate. Secondly, Hyldespjældet's architectural style shows mixed traits from the 70's BAUHAUS and Art Deco styles in terms of colours, shapes, sizes and materials. Finally yet importantly, the neighbourhood inherited structural solutions from Albertslund in terms of separation of means of transportation.

Hyldespjældet, similarly to Albertslund comprises relatively large amount of green spaces, approximately 35% percent of the total area, and a high number of green elements such as grass areas, trees, bushes and green roofs scattered throughout the neighbourhood. As it has been mentioned before, vegetation has several positive impact on urban areas in multiple ways. Additionally, nature and green elements have just as important effect on personal health, general wellbeing and even in sociological levels.

Accordingly, in the case of Hyldespjældet, nature has a key role in identifying and keeping the local community together, since the neighbourhood is renowned for its environmental friendly attitude, sustainability related initiations and its strong, dedicated community. Besides that it is an open space exhibition of sculptures all year long. Thanks to the initiations from local residents, Hyldespjældet has great potentials to step further towards an utopistic urban model, by: zero CO₂ neutral homes, smart homes, no independence on non-renewable energy sources, circular economy, bio-farming, electric cars, most efficient and human centred lighting, strongly engaged and sharing society, sharing economy. Some of these goals have (or partly have) been fulfilled already and considering the development process of Albertslund the rest might follow up in the near future. These more or less distant development processes has to be taken into consideration during the design process in order to fit into the larger scale with a new lighting design.

Regarding Hyldespjældet's spatial structure, based on participant observations and informal interviews the centric green space with the "Harry Potter" playground turned out to be on top of the outdoor space hierarchy in terms of dimension, functions, attendance, nature density and maintenance. This area absolutely has potential to get people together, therefore could play a key role in this light refurbishment project, which aims to extend and raise social activity in the dark hours with a new and innovative lighting design.

The second most socially active area is around the café. Multiple functions attract people there, but mostly indoor activities are accommodated in that zone, which are scarcely affected by public lighting. In addition, the close surrounding of the café is going to be refurbished in the next years, but the initiation lacks a final plan yet, therefore it is very challenging to focus on this space's specific lighting design, and is out of the current project's scope.

The current state of street lighting in Hyldebjerg is slightly chaotic and at some points problematic in terms of:

Colour temperature (CCT) differences	(1800K – 5800K)
Illumination (lux) differences	(2 – 70 lux; measured under fixture)
General condition differences	(poor condition – new)
Light source types differences	(HPS, Compact fluorescent, LED)
Obsolescence	(old technology – up to date)

During the measurements, the author of this report met some of the residents, and conducted short informal interviews with them about the lighting. Interviewing techniques were used from Robert K. Yin – *Qualitative Research from start to finish*, 2011. According to interviewed persons, Hyldebjerg's lighting system is unanimously considered satisfactory. As problems, people mentioned the glare effect and the significant difference in colour of the new LED street lamps (*Figure 10*), and missing or malfunctioning luminaires. Some mentioned that the main Harry Potter playground and park could have some lighting since it was a popular area, and a few of them complained about lack of safety regarding the unlit spaces along the border backyard lanes. Nonetheless, during the first meetings only modest interest could be observed on behalf of the local residents in lighting refurbishment.

The following table summarizes the main findings of the pre-analysis chapter - the features of the site, and the project, that have an effect on the design formulation. Strengths can provide basis, opportunities might be utilized to create something valuable, weaknesses have to be fixed and threats should be taken into consideration to minimize their impact.

Strengths	Weaknesses
<ul style="list-style-type: none"> - several eco initiations - human scale - well maintained integrated green spaces with multiple functions - number of existing fixtures - nice atmosphere in side streets - warm colour temperature luminaires at most places 	<ul style="list-style-type: none"> - mixed old and new lamps - mixed colour temperatures - faulty street lamps - glary street lamps - obsolete light source types - too high illumination at certain places - no illumination at recreation areas - no illumination in backyard lanes - no illumination on the bordering paths
Opportunities	Threats
<ul style="list-style-type: none"> - divergent street structure - numerous artistic element - service / function focus areas - unique architecture - unique street equipment - infrastructure for a new lighting design - lamps for every apartment entrance - support of eco-friendliness in the local community – green transition initiatives - no illumination at recreational areas 	<ul style="list-style-type: none"> - multiple stakeholders in the project - lack of local interest in lighting reform - uncertain planned renovations - cost of the renovation for ~470 lamps - chaotic documentation of maintenance

Figure 11. SWOT analysis

Among strengths, the author found that the most beneficial characteristic of this neighbourhood is the human scale, which appears in the extents of Hyldebjerg itself, the low resident number, the building heights, apartment sizes, the open

outdoor space sizes. Besides these physical attributes, local groups (gardener group, chicken farm groups ... etc) and their activities and initiatives make a personal atmosphere, and brings the interpretation of human scale to further levels.

Regarding the explored weaknesses, the first issue is the chaotic state of the current lighting system. The main problem although, from the point of this lighting refurbishment project, is that recreational areas are unlit. Apart from functional street lighting, there was no specific lighting for any recreational area. There was no lighting at the large green spaces, at playgrounds, at the pet playground, and no light for the concrete basketball court either. Thus, use of these spaces is diminished in the dark hours, which is a significant issue considering the short Danish daytime length in the wintertime. At multiple sections, those areas were completely isolated into darkness by bright street lamps with a non-shielded light source. With this way of lighting, visibility is restrained to the lamppost itself and the brightly lit sidewalks, and all the surroundings are covered into undiscoverable darkness. Regarding the new design, these issues call for a solution.

Despite the significant weaknesses, numerous opportunities has been discovered as well, and the lack of illumination at recreational spaces is one of them. This missing element provides options and a relatively great freedom for an new lighting design. The two functional focus points of Hyldebjerg are also important to be taken into account, when the main goal is to entice people outside and make them spend time together. Most important however, are the unique characteristics of the street web, buildings, facades and street equipment like the typical mailboxes that all facilitate creative ideas and solutions for the design.

Threats are rather related to the project and its goals, not to the creative process of the new design. From the beginning, it was clear that this project requires special care in management, since there were four collaborators (AAU-CPH, DONG Energy, Albertslund Municipality, Lighting Metropolis) and additionally user involvement was strongly emphasised. The latter meant multiple discussions with the local representatives. Therefore, in total, there were five stakeholders that the communication and cooperation had to be managed among. Another difficulty was encountered during the meetings with local representatives and interviews with locals, namely the modest interest in a new lighting system. Additionally, in the near future (next 5 years) significant refurbishments of buildings were planned, where the indoors and the outdoors are both involved. Despite that, the changes had been planned, there were no finalized documentation of it at the time of the writing of this report. Changing the

building, and therefore also the street characteristics is a significant modification, and the lack of the final plans requires even closer cooperation among the project partners to create a proper, adaptable design.

Problem statement

Based on the previous chapter's summary, regarding lighting, the main problem, besides the chaotic CCTs and light sources, is that the recreational areas have no lighting. They are isolated into darkness, therefore use of them is prevented at night time. A problem statement has been formulated in order to identify the essence of the shortcomings of the current lighting state, and to give a certain direction to the design process:

“Public spaces in Hyldebjerg are scarcely used in the night time by the local residents in lack of appropriate lighting”

The problem statement also defines a research direction of the next chapter, to find the lighting parameters that make a public lighting appropriate. Under appropriate, the author means a non-conventional, aesthetically pleasing, lighting design, that has the potential to entice people outdoors. As an answer to the problem statement, along with the project requirements, a hypothesis has been developed, to define the final project goal with an appropriate lighting. It reads as follows:

“A new lighting design with interactive and innovative elements generates social activity and interactions at night-time at public spaces, thus strengthens the local community.”

The hypothesis also works as a design evaluation tool, since it defines project criteria that can be analysed subsequently if achieved eventually or not. In this case criteria are:

innovation

learning effect on users

extended and raised outdoor activity

strengthened bonds among residents

Evaluation of meeting the criteria will be unfolded later in this report.

Analysis

Design scope

Deriving from the initial project goal, the design aims to deliver solution to the exposed problems on two scales. One is a greater scope, the refurbishment of the street lighting of entire Hyldebjerg, the other one is to create a specifically interactive and innovative lighting design at a focus area to entice people outside and give them the opportunity to use that particular public open space to a further extent.

According to Gehl, streets can assemble or disperse people. (Gehl, 1971). Streets are the primary public spaces. Once we step out of our home, they are the first venues of interaction with the outer world, with other people.

Hyldebjerg's case is special, since the divergent sub-street structure disperses people, and provides ample possible routes, but at the same time, most of the streets lead either to the central green space or to the café area, the two functional focus points of the neighbourhood. Streets of Hyldebjerg disperse people but also assemble them at the same time by leading them to the two centres. Furthermore, the narrow streets are designed for slow transportation, which makes them inviting and appropriate for socializing. (Gehl, 2011). Therefore Hyldebjerg's streets have a significant potential to contribute to achieving the project goal, increasing social activity, by being venues of social interaction. According to the hypothesis, an appropriate lighting design would induce outdoor activity also in streets, but evidently, there are more options at places where there is space enough and multiple functions already exist to entice people.

Such outdoor open space in Hyldebjerg is the central green area. It is the most adequate spot for a focused design from multiple aspects. The area is large enough for outdoor activities for many people at the same time. It has multiple functions (detailed in the pre analysis). A wide range of age groups visit the place almost every day. It is situated in the middle of Hyldebjerg, and several streets lead to it. The area is grass covered and comprises trees, bushes, flowers, which have significant positive effect on health in general.

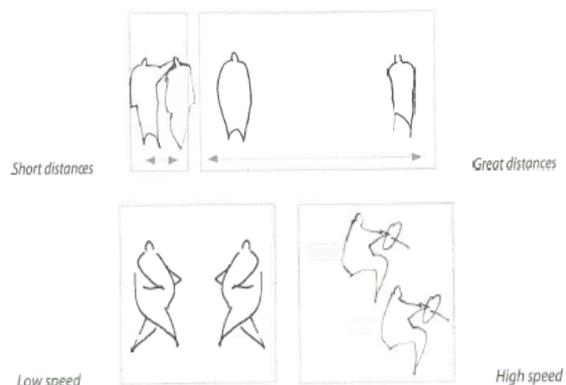


Figure 12. Jahn Gehl – Life between buildings, 2011

Overall, the design proposal of this report aims to deliver a design, in which streets and other open public spaces, especially the centric green area, constitute a coherent whole, regarding that in Hyldebjerg's case streets' physical attributes are very appropriate to facilitate the project goal, outdoor social activity and interaction.

Further investigation of the Analysis chapter aims to define "appropriate", mentioned in the problem statement, regarding outdoor lighting by analysing data of relevant studies. Gathered findings will be translated to the case of Hyldebjerg subsequently. Investigations went along the following keywords, defined based on the pre-analysis findings, the problem statement and the hypothesis:

"Outdoor", "Public", "Social", "Space", "Activity", "Lighting", "Interaction", "Nature" and "Health".

Since the core of the initial project goal is street lighting development, and streets are common open spaces for people, "outdoor", "public", "social", "space" and "lighting" keywords are straightforward. At the same time, this study aims to generate activity and interaction between people and light and between person and person, which describes "interaction". As it was figured out in, the pre-analysis, natural spaces and vegetation are an essential part of Hyldebjerg's identity and local's lifestyle. This finding involved further investigation of vegetation's effect on people, society, and especially the relation of lighting and plants and perception of nature at night ("nature", "health").

Definition of appropriate:

It is well researched and confirmed that improved lighting increases pedestrian activity. (Schroeder, 1989). The increased activity relates to better night time visibility, a higher sense of safety, and to the fact that higher contrast and greater intensity differences are raise interest, up to the point when they do not cause glare (Rea et al., 2010; Farrington, 2008; Fotios et al., 2014; Nasar and Bokharaei, 2016). Therefore diminishing the glare of Hyldebjerg streetlights and providing the minimum required 2.5 lux in all the streets would already have a positive impact on outdoor activity, however, intensity is only one factor of light. Researches state that conventional lighting might not be a guarantee to attract people to a certain space (Cortés & Morales, 2016). An enticing lighting design has multiple factors.

Several studies investigated effect of lighting on people from multiple aspects. Most of them assessed feelings or moods related to different variables of lighting, as colour temperature, colour distribution, light distribution, brightness and

placement related to user position. According to Calvillo Cortés, there are 10 frequent lighting's emotions: pleasant, surprise, inspiration, affection, fascination, entertainment uncertainty, fear, unpleasant surprise, contempt and disappointment. A study from Calvillo Cortés from 2016 has investigated these terms in relation to parameters as intensity, colour, direction and diffusion. The study finds that high-intensity and focused lighting are related to emotions that involve more action and movement, such as entertainment and fascination, whereas low intensity and blurred quality lighting are related to emotions that involve affectivity in a positive or negative sense, such as fear or affection. Observations of the study showed that colour and direction are related to emotions that involve originality, such as pleasant surprise or fascination.

To sum up the study's findings, a lighting installation evokes positive feelings such as entertainment, fascination, pleasant surprise and positive affection and entices people much more significantly if it incorporates colours, high intensity light spots, highlighted focus points, subtle peripheral lighting, and low intensity lighting areas at the same time.

Regarding the social manners and community related aspects, a study of a residential area's lighting in Copenhagen, Denmark, states that visibility and lighting practices create a sense of community, by revealing the neighbours to each other. The study also says, that light and the lit and visible movements indoors and outdoors indirectly connect people but direct communication is a more delicate matter. (Brille, 2013).

Another study from 2013 tested three different interactive scenarios for a public square lighting in Aalborg Denmark. One of it was a wind velocity responsive ambient lighting, another is a mobile application based colour control, third is a movement detection triggered colour change. The result of the study showed that in the latter two cases people stopped, spent more time at the square, established interaction with the light, and with each other. The most significant effect on social behaviour was triggered by the movement detection based interactive lighting. Flying gestures, running and dance moves were common reaction from pedestrians, and that made others stop, and enticed them to join the play, therefore created a spontaneous interaction between people as well. (Poulsen et al., 2013)

Other studies regarding human outdoor activity, found that green elements, such as grass areas, bushes, trees, and water surfaces have conditioner effects. These effects prolong outdoor physical activity, thus facilitating more human interaction. (Berkman, 2000). Attractive green areas in the neighbourhood may serve as a focal point of tacit coordination for positive informal social interaction, strengthening social ties and thereby social cohesion (Kweon et al., 1998). Social

cohesion by itself is thought to have a positive effect on well-being and feelings of safety (Groenewegen et al., 2006).

Correspondingly, these statements are strong arguments to involve Hyldebjerg's central green area into the design and to create a spot specific light interaction there.

Reference projects

According to the analysis conclusions, three relevant and already implemented projects will be briefly introduced in the followings, to give a better understanding of how the above-mentioned lighting parameters can be applied in a proper way.

Finsbury Avenue – London



Figure 13. *Finsbury avenue – Maurice Brill, google.com*

This project designed by Mark Ridler – Maurice Brill Lighting Desing, applies glowing stripes mounted into the walking surface at an approximately 1850m² public square in London. The stripes are addressable and with the programmed pre-sets, several different patterns can be shown (see labyrinth in in figure X). The installation greatly improved the place’s popularity and attendance, and even though people have no direct control over the colours and patterns, pedestrians tend to stop and play with the light. Just as in the case of the study from Aalborg, playing with the light broke down the primal borders between strangers meeting at a public space and established social interactions. Colours, great contrast, unique placement as “wow factor” are all contributing parameters to make the design unique and adequate to affect human behaviour. Furthermore, accentuation of vertical objects is also part of the design, to provide sense of depth, and airy, human scale space walls at the same time. Accentuation of trees is also an important element of this project, not only to create verticality, but also to ease the artificial atmosphere of the futuristic ground installation, with the positive effects of vegetation.

Dune – Studio Roosegaarde



Figure 14. *Dune* - Roosegaarde, google.com

Dune is an innovative light fixture of Daan Roosegaarde, the Dutch artist. It has been exhibited multiple places throughout the world. The reed-like sticks are bendable, and a transparent top glows in the dark. The installation comprises sound and proximity sensors, and responds to human interaction with brightness changes. At the end, the induced effect is organic looking and evokes the appearance of an enchanted wind-blown field.

This project incorporates light and lighting into a fixture with a naturalistic look, and creates interaction with light that further accentuates the organic atmosphere elicited by the glowing sticks. Dune is a brilliant combination of light and the beneficial effects of nature, enhanced with human triggered interactions. Except of different using colours, Dune applies all the previously mentioned parameters of an appealing lighting design, though similarly to Finsbury Avenue, it does not provide great visibility and functional light.

BruumRuum! – Barcelona



Figure 15. *BruumRuum* – Artec3, google.com

This installation invites pedestrians to participate in turning the entire plaza into a glowing game in which the sounds of city life become a visual light effect. The installation combines colour and sound through 522 luminaires embedded in the surface of a 3,300m² area. The LEDs respond to the intensity of voices and ambient city sounds via sensors installed around the plaza, thus involve users to be the artists of the place. Participants tend to stop, shout into the microphones, laugh at it, and talk to each other. A great example of how the interaction with sound and coloured light brings people together and created social activity.

DESIGN

The design proposal of this report aims to deliver an appropriate and enticing lighting design for Hyldebjerg, based on the previously detailed lighting factors. The final design incorporates:

1. colours
2. psychological effect of colours
3. contrast
4. intensity variations
5. placement variations
6. interactivity
7. innovation
8. connection to nature

As it has been mentioned before, the proposal has two scopes, a greater general street lighting, applicable for entire Hyldebjerg, and a spot specific design for the space with the greatest social potentials, the Harry Potter playground area.

Street lighting design



Figure 16. Side street lighting - 360° panoramic visualization

The most characteristic feature about Hyldebjerg is absolutely the look of the facades. The interplay of different pastel colours of doors and windows, and the brown-red walls provides a bold basis for a lighting design, which incorporates colours. Instead of the glary and obsolete wall mounted luminaires that hang beside every entrance door, this proposal suggests linear addressable RGB LED fixtures embedded into the wall gaps next to each entrance door. With this delicate placement and with a diffuser material on the lamp, glare issues of the currently existing luminaires are expected to be prevented. At the same time, this solution provides vertical illumination, therefore better orientation in space, feeling of safety, and facial recognition (Fotios et al., 2014) The fixture would provide interactivity as well (detailed later on), but at the idle state it would be a two meters long light line, operating at 3000K CCT. The idle colour has been chosen based on common street lighting practices.

Since this fixture is addressable, and mounted next to each entrance, it becomes a personal lighting for each apartment owner. This proposal suggest a mobile application to control the lights, similarly to the Philips Hue lights. Owners could control their own fixture next to their entrance door. Ownership over a lighting fixture, which is part of the street lighting, extends ownership to over the streets as well, since the lights are essential parts of the street's appearance. According to the study at Aalborg from 2013, people felt the space more their own and more personal when they had control to some extent over the street lights. By incorporating the façade lights into the street lighting system as a partly functional partly scenographic layer at the same time, a similar effect of affection is expected from the local residents.

Control over the lights is proposed to be limited in terms of certain colours, and time duration. Blue (and high energy visible, HEV) light is known to be unpleasant under certain circumstances, due to that it is a high-energy electromagnetic radiation that might cause eyestrain and damage the retina, and due to the fact that it is hard to see a blue light source clearly, since blue light scatters more easily than other visible wavelengths.(www.bluelightexposed.com). Harsh blue and violet colours therefore are excluded from the proposal, as optional colours. Furthermore, the customized state of the lamps would be restricted to one hour at a time, in order to prevent forgotten fixtures disturbing the neighbours in the front. In the last 10 minutes of the set up hour, the duration of the custom colour could be extended by another hour. The owner of each apartment could also allow through the application for other local residents or pedestrians to access the fixture via a general local Wi-Fi network.

By having personal ownership over the luminaires, and this active level of interaction, countless possible variations could be designed by locals, recreating

the effect of the famous Nyhavn in Copenhagen, or indicating the location for guests, highlighting their homes during celebrations as Halloween ... etc. This way, users would be involved into designing their habitat even after the installation is done, which is a step further in participant involvement design.

Besides the direct control over the fixtures, which might entail threats like low willingness or low interest in controlling, the vertical façade lamps are designed to support an inactive interaction as well. Multiple scenarios has been worked out based on the pre-analysis and analysis findings of this report.

No. 1

Thematic route to the Café. Every Tuesday and Thursday night when the local café is open for dinners, a route would be indicated by a 30cm long turquoise lit section on the top of the light bar, leading people to the event. On their way, people oriented by the coloured façade lights, could meet fellow “light followers”, and establish social interactions with them. The route would be different each week, in order to provide novelty and the experience of exploration every time.

Turquoise has been chosen specifically for this theme as a social interaction activator colour. Psychologically, turquoise represents clarity of thought and communication. It inspires self-expression, encouraging people to tune into their own needs. Physiologically, turquoise calms the emotions and recharges the spirit, invigorating depleted energy levels and inspiring positive thought. (Cerrato, 2012)

This theme is expected to remind people to participate in the event, to entice them to choose the highlighted path for a “hyggelig” cosy walk as a preparation for dinner. During this walk, social interactions such as discussion is expected to be established among strollers.

No.2

Friday nights, a weekly changing path, highlighted with purple light would connect the two functional focus points of Hyldebjerg, the café area and the central green space. The indication would be at the same place as in scenario one. The goal of this theme is to lead people through Hyldebjerg and make them explore it and the numerous exhibited art elements, while providing opportunity to meet others. The purple colour is chosen because it is associated to mystery (Cerrato 2012), and it is expected to create an exciting atmosphere for exploration.

No.3

Every Sunday / Monday night there would be an hour in line with the sunset time, when the vertical light bars would indicate the eco friendliness of the household. Used and produced electricity (by solar cells) and used water would be measured and the proportions would be translated to the luminaire, in a form of a light

green bar from bottom to top. The friendlier the apartment was, the higher the green bar will reach. The rest of the fixture would be lit 2000K CCT. Since environmental friendly initiations are popular in Hyldebjerg and are trademarks of the neighbourhood, this comparison challenge is expected to boost the growing eco-friendliness. The glowing charts are expected to entice people to stroll around in the neighbourhood and check who consumed how much. People would meet their neighbours, establish conversations, and deepen their bonds to Hyldebjerg and to each other as well, thus strengthening the local community.

Another key element of street lighting is proposed to be mailbox lights. Warm white LED plates with 3000K CCT on the bottom of the existing mailboxes, that are characteristic components of Hyldebjerg's street look. Giving them a new function would raise their role onto a new level where and transform them into "mailbox bollards". This transformation, beyond aesthetic reasons, has logical functional arguments as well. Since mailboxes belong to each apartment, there are many of them along the pavement of streets, and their distribution is even more beneficial than the current wall mounted lamps. Mailboxes are in hip height, which allows aiming light across the pavement and providing good light distribution. With the mailbox lights a purely functional glare free, better distributed and more uniform horizontal street lighting is expected to be created, a complementary to the vertical facade lighting.

In wider streets, where buildings face the opposite direction, or where there are no buildings at particular sections, such as the main roads connecting Hyldebjerg to its neighbourhood areas, regular lampposts are proposed to be maintained as street lighting elements. (Figure 16).



Figure 17. Main street lighting - 360° panoramic visualization

According to Albertslund’s regulations there are three possible types of street lights, and this report proposes the Albertslund lamp, which has been implemented and certain points of Hyldebjergvej already. These lamps though, need a revision, because they have different colour temperature LED-s and brightness levels are also chaotic at the moment. The proposed CCT is 3000K in the case of this luminaire as well.

The proposed RGB LED bar is suggested to be a Martin Pixline 10 lamp, two pieces on top of each other.

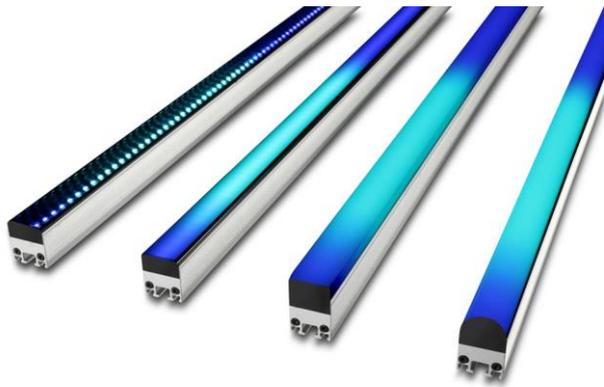


Figure 18. *Martin pixline 10, martin.com*



Figure 19. *Martin pixline 10, aarhusupdate.dk*

Dimensions	27mm X 74mm X 2000mm
Light source type	RGB LED (100 pieces / meter)
Watt	33W/ meter (max. with full white)
Luminous intensity	750 lumen/m
CCT	RGB

Figure 20. *Martin pixline 10 specifications*

Dialux calculation

In order to prove the design’s feasibility in terms of street lighting illuminance levels, uniformity and light distribution, a prototype has been built in DIALux EVO. For the test measurements, a narrower street has been modelled, with building blocks, thus mailboxes and façade lights on both sides. The façade lights were simulated with the official Martin LDT light characteristic file. Mailbox lights has been approximated by an iGuzzini bollard (Outer Oblique) LDT file, since it was close to the mailboxes in size (~ 40cm x 20cm), and matched the low luminous intensity requirements of Hyldebjerg’s case.

As it turned out, the façade and the mailbox lights together can provide the required 0.25 uniformity value, and with site-specific calibrations (dimming), the average 2.5 lux is also achievable.



Figure 21, DIALux simulation of a sidestreet

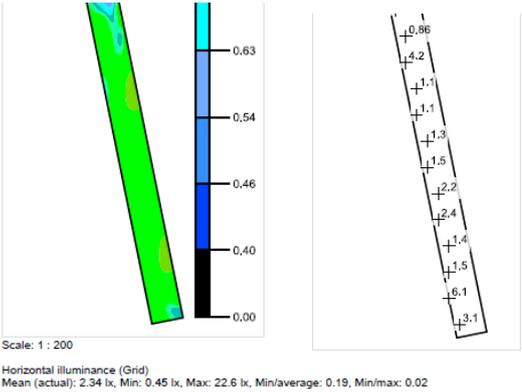


Figure 22. Lux values on the sidewalk in DIALux

Harry Potter playground area lighting design

“Lighting in the landscape creates a mood, an atmosphere an imaginative effect – a feeling that is powerful and lasting, but without self-consciousness or showy extravagance. Landscape after all is not an object to be highlighted, but a field, a texture of duration, passage and elemental connectedness with nature.”

(Descottes, 2011)

Landscape lighting



Figure 23. Lighting design of the natural area beside the playground - 360° panoramic visualization

In the case the Harry Potter playground and its close surroundings, we are talking about a natural area with significant amount of vegetation. As it has been mentioned before in this document, that area is in complete darkness at night, and the surrounding street lamps only accentuate the isolation, since they provide a great intensity contrast right at the borders of that area. This proposal therefore suggests a design that brings nature and landscape to life at night, opens up the yet unlit dark areas and washes the borders of lit street and unlit nature, by subtle tree up lights that would replace lampposts around the playground area. According to what Descottes states, the purpose of the tree up lights is not to

highlight particular natural objects in the landscape, rather to give a texture to space.

Since the vertical and horizontal street lighting elements are expected to cover official lighting requirements, the up lights' role is only to extend space and give orientation in it. Up lights are proposed to operate with 3000K CCT, just as the rest of the street lights.

Tree up lights are proposed to be iGuzzini earth ground mounted luminaires.



Figure 24. iGuzzini Earth up light luminaire, iguzzini.com

Dimensions	250mm X 201mm
Light source type	LED
Watt	12
Lumen output	1800 lumen
CCT	3000

Figure 25. iGuzzini Earth up light specifications

Harry Potter Playground lighting

As the design principle of the tree up lights was to extend space and bring the landscape and nature closer, the following luminaire proposal is a continuation of that idea. The iGuzzini Typha lamp imitates reed, see Figure 23. By its semi natural, semi artificial and magical glowing look, it would the transition between the lit buildings, sidewalks, artificial elements, and the real nature. With its subtle glow the Thypha creates the atmosphere of an enchanted field, which is ideal for a playground. Kids therefore can step into another world created by light.



Figure 26. iGuzzini Typha luminaire, google.com

Dimensions	12mm X 1500mm
Light source type	LED
Watt	1.5W
Lumen output	50 lumen
CCT	4000K

Figure 27. iGuzzini Typha specifications



Figure 28. iGuzzini Typha at the playground

The Typha is made of plastic, and is bendable, thus provides physical interaction which is a great feature, especially from the aspect of children, who could play with the light itself. This lamp creates mood and atmosphere, links lit streets and nature together, and facilitates interaction.

Another proposed interactive light element is lit stepping-stones, with subtle greenish fluorescent-like glow, see Figure 26. The tiles would be pressure sensitive, and the game would be the following: When at the idle state someone steps on one of them, the game begins, and one of the tiles glows up brighter. The brighter stone has to be chased by stepping/jumping on it. Sometimes there would be two optional stones to jump on. By time, the highlighted tiles would be farther from the previous one. There would be also a waiting time within the pressure is accepted and the game can go on. This delay period would decrease gradually. Exceeding the time limit ends the game.

The panels could generate electricity from the mechanical energy of the steps, thus support themselves. An eco-friendly element like this would perfectly fit to the neighbourhood's image.



Figure 29. *Harry Potter playground and the stepping stones*

As the playground got his name from the wooden “Harry Potter” castle, it constitutes the most iconic and significant element of the area in terms of appearance and uniqueness. Forming a lighting design for this structure had the most potential to create something outstanding, something bold that might enhance an existing local trademark, or almost become a new itself. Three themes has been designed for the castle, listed below.

Idle state – ghost castle with cool white lights



Figure 30. *Harry Potter playground – ghost castle*

White is the colour of simplicity (Cerrato, 2012), therefore causes the least disturbance effect for locals when the playground is unused. White light combined with deep shadows create a harsh contrast with undiscoverable unlit areas. Latter effect together with a ghostly white glowing creates a spooky atmosphere, an exciting challenge for kids to explore the castle at night.

Theme of burning fire (red/yellow composition) – extinguished fire (nuances of blue)



Figure 31. *Harry Potter playground – burning fire*



Figure 32. *Harry Potter playground – extinguished fire*

This theme is interactive with mechanical touch sensors in the different rooms and units of the castle and throughout the playground. After a touch, fire is extinguished and red turns to blue. Once all fires are extinguished, castle goes back to idle white state until the theme is activated again by its start button. This theme is expected to encourage kids to run around, extinguish fire where led light appears, therefore creates a tag game-like interaction with light.

Theme of creative imagination



Figure 33. *Harry Potter playground – creative imagination*

This theme incorporates green and violet colours, which are split complementary colours of each other. Split complementary colour pairs represent a more harmonious and less harsh contrast than complementary pairs, but still achieve to stand out and draw attention. Besides, green and violet have individual positive meanings and unconscious effect on humans.

Green is associated with nature, harmony, growth and freshness. Green has strong emotional correspondence with safety, thus easing the spooky and aflame castle themes. Psychologically green relates to balance and harmony of the mind, the body and the emotions. Green is the most restful colour for human eye, it has healing power and suggests stability and endurance. Green also encourages generosity, kindness and sympathy. It also motivates people to join social groups and satisfies their need to belong, which is beneficial on a society level too, especially at a main meeting point. Using green colour aims to generate a mild and safe environment, a shelter for kids. Green light gives a natural looking atmosphere, therefore extending and accentuating the area's green nature. (Cerrato, 2012)

Purple combines the stability of blue and the energy of red. Purple is associated with wisdom, creativity, mystery and magic. Almost 75% children prefer purple to all the other colours. It also conveys extravagance. (Cerrato, 2012) Purple creates an immersive fairy tale kind of atmosphere with high pleasantness to kids, and encourages creativity.

For the castle lighting, RGB outdoor LED strips or bars are suggested, see the example fixture list below:

Adafruit NeoPixel digital RGB LED strip

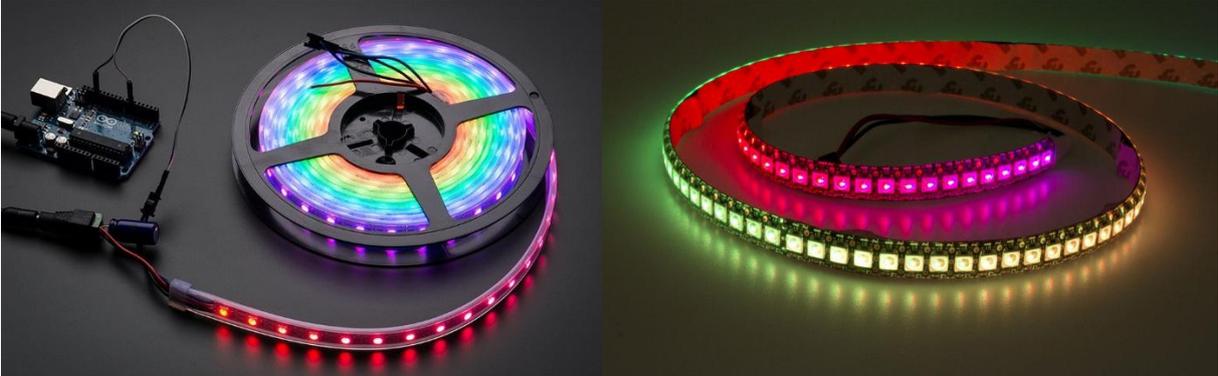


Figure 34. Adafruit addressable RGB LED strip, cnd-shop.adafruit.com

Dimensions	12.5mm X 4mm X 1000 mm
Light source type	RGB LED (60 pieces / meter)
Watt	4.62 W/ meter
Luminous intensity	50-340 lumen/m
CCT	RGB

Figure 35. Adafruit led specifications, cdn-shop.adafruit.com

Martin PixLine 10

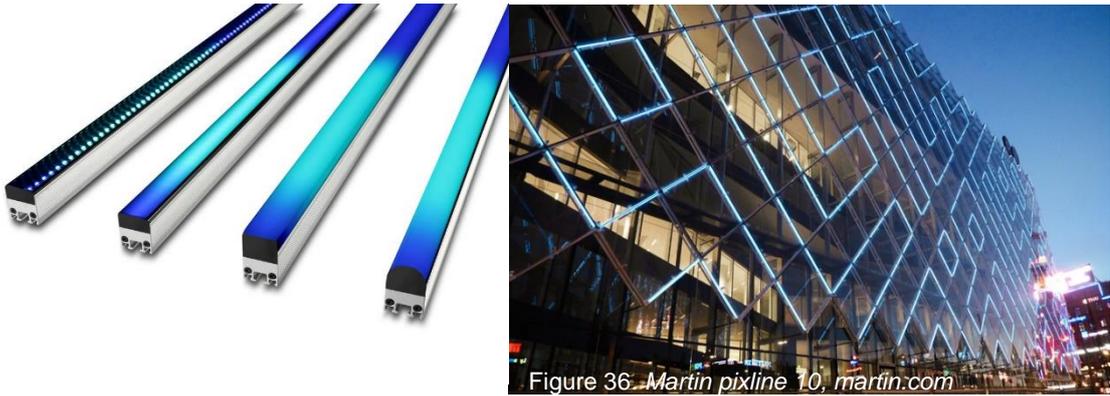


Figure 36. Martin pixline 10, martin.com

Dimensions	27mm X 74mm X 2000mm
Light source type	RGB LED (100 pieces / meter)
Watt	33W/ meter (max. with full wite)
Luminous intensity	750 lumen/m
CCT	RGB

Figure 37. Martin Pixline 10 specifications, martin.com

Discussion

The following chapter will evaluate this report in to subchapters. The first one focuses on the design, and how the proposal answers to the findings of the reference studies, how it synthetises the gathered knowledge. The second one unfolds how the triple helix model worked in this project, the collaboration among the parties and how user involvement and participatory design was realized.

Design

To set up an information basis for the design, the pre-analysis chapter aimed to collect knowledge about the site, Hyldebjerg. Spradley's theory was used to conduct on site descriptive observations. The collected information was categorised to subchapters in the pre-analysis, as general/historical information, demographic data, spatial structure, users, architecture and lighting.

All this information was supported with some local user feedback (user involvement unfolded later in this chapter), and in collaboration with the DONG Energy and the Albertslund municipality representatives, a design direction, a framework has been worked out together. As it has been unfolded in the analysis chapter, the design proposal aims to achieve the "appropriate" outdoor lighting. Under appropriate, this report means functional, appealing, exciting and enticing. To find the answer to the question what the factors are of appropriate lighting, several scientific research on public lighting has been studied.

A lighting to be functional and to provide a scenographic layer at the same is challenging, if not controversial. Functional street lighting has the focus primarily on uniformity and horizontal illuminance requirements within the range of 3000-4000K CCT. Higher uniformity and illuminance facilitates better visibility in general, and the 3000-4000K colour temperatures are considered to be the most conventional and satisfactory in street lighting. In contrast, exciting, appealing, and enticing adjectives are generally related to different installations. According to the reference studies, these responses from test participant were evoked, when the lighting comprised the following factors: colours, contrast, bright focus points and private darker areas, sense of orientation, sense of safety, non-conventional placement, horizontal and vertical light distribution, interaction with the lighting, control / ownership over the lighting. These terms has become the criteria for a successful design for the Hyldebjerg project.

The design proposal of this paper combines all these attributes and creates a coherent, layered interdependent system. In the case of street lighting, mailbox lights provide pure practical functions, with only low distributed horizontal illumination. The vertically placed façade lights in turn provide vertical illuminance for facial recognition, and orientation, thus improving visibility and expectedly safety as well. The façade lights also incorporate colours, contrast, non-conventional placement, interaction and ownership into one delicate fixture.

Theoretically, the design proposal achieves to be an “appropriate” lighting by combining all the scientifically proved parameters subtly and delicately in two cooperating luminaires, while simplicity has been preserved.

The main innovation of this proposal is that functionality and aesthetics are incorporated into street lighting, in a way, that the lighting itself can make people go outdoors and meet each other.

The same socializing effect is expected from the playground area, but instead of focusing on functional lighting, focus is on nature accentuation there, since nature and sight of nature has positive psychological and physiological effect on humans (Groenewegen et al., 2006). The innovation of the playground lighting is that it enhances the effect of nature with light, on physical and on virtual realms as well.

To observe people’s reaction to the design proposal, 360 degree rendered images were shown to them with Samsung Gear VR glasses, for a more immersive experience of the simulated environment. Unfortunately the participants were not residents from Hyldebjerg (explained later), however all participants had been introduced to the neighbourhood by photos. After that, they could observe the design from six different positions in full 360-degree view angle. Their feedbacks were positive regarding the question if they found the design interesting and whether it would make them go outdoors to explore the lights. These feedbacks support and confirm the theoretical framework of the design principle, though local resident’s responses would have been more relevant and valuable.

However, seeing a visualized design proposal and experiencing an atmosphere in real life might be very different, therefore the actual responses can only be collected by representing a physical installation. Within the time frame of this report, a physical demonstration was not possible.

Project management – User involvement

Involvement of local residents into decision making in the design process was pushed by the beginning of this project. Therefore, after the first individual data collection by the author, in order to acquire further understanding of the neighbourhood and its society, a meeting was organized with locals and the three Lighting metropolis partners, DONG energy, Albertslund Municipality and Aalborg University Copenhagen. A questionnaire had been optimistically prepared for 40 people, but only seven showed up on behalf of the residents, the local representatives, who were responsible for different social activities, such as maintenance of common green spaces, common website, local newspaper, Facebook group, sculpture park management and financial management of Hyldespjældet. The prepared questionnaire turned to be too difficult to answer for them. Questions were related to frequently used routes throughout Hyldespjældet, but none of them was able to draw one prioritized over any other. Even though the representatives were unable and slightly unwilling to answer the questionnaire, as a result, it was figured out that Hyldespjældet provides several alternative route possibilities, and locals tend to alter their way. This information later formed basis for design ideas.

At the same meeting, possible design directions were also discussed among the present parties. From that moment on, the representatives of DONG Energy and Albertslund municipality met the author of this report several times, to work out the principle of the innovation, and the test area of the project, since the budget did not allow to implement any design full scale right away. About the meetings' outcomes, locals were kept informed on their common Facebook group, where reactions, feedback was also expected. It was realized, that even though information and questions had been communicated to a wider user group, respond rate did not raised. For three detailed design direction proposal written in Danish, supported with inspirational images, somewhat 10 responses were documented. Some of the responses even opposed a lighting refurbishment project in the neighbourhood, since there were other ongoing, unfinished ones in other fields.

It was learned, that user involvement is an elaborate matter, and might not give any useful input, without preparing some more concrete presentation material. Therefore, the next meeting with locals has been shifted for later, in order to create visual content of the design ideas for the locals. The author consulted several times with the DONG Energy and the Albertslund municipality representatives, introduced his ideas to them as primary parties of the project, and created a deliberate design, which gives solution on multiple scales

(interactive and innovative street lighting, and scalable, thematic, interactive spot specific lighting).

After presenting the final design to latter two parties, despite of the anticipatory agreement on design elements, the proposal's welcome was doubtful. Due to communication issues among the collaborating parties, and within Albertslund municipality, and regarding the projects authority, the budget, the design and the time span had to be modified.

Shortly after the presentation of the final design proposal, an official Albertslund regulation has been released, which defines a list of lighting fixtures meant to be used throughout Albertslund. Any deviations from the list, entails a long acceptance process that might postpone the project's realization, and besides, DONG Energy has financial interest in using the defined lamps.

Regarding authority problems, the municipality has to cooperate with BO-VEST, the housing company, which maintains the buildings, the utility system, and the green areas. Therefore, any lights that's mounting somehow physically affects the apartments, or any green areas, has to be approved by BO-VEST which makes the procedural structure even more complicated. In order to accept a design, local residents has to vote for a street lighting fixture from the list, a design has to be created with applying that particular fixture, then it has to be accepted by the collaborating parties and the locals and finally BO-VEST has to approve it as well.

The project was planned to operate from two financial sources. One was a specific Lighting Metropolis fund, set aside for financing elements of innovation. The other, greater part was a share of Albertslund municipality's lighting budget. However, due to political and unknown issues, the planned money from Alberslund municipality, has not been allocated from the annual budget, which means a great cut from the financial resources of the project, and therefore limits the design options.

To sum up, this report's design proposal has been rejected, due to the Albertslund lighting regulation lamp list, the circumstance that BO-VEST company is in verdict position about the design's proposed elements and finally, due to the great shortage in the budget.

After all, before the submission of this study, the previously detailed difficulties still existed, and not even the project focus was clear anymore (playground lighting or street lighting innovation). According to time limitations, the design revision is not concern of this report.

Conclusion

Outdoor public lighting is well researched from practical aspects, like uniformity, illuminance levels, light distribution, sense of safety, preferred spectral distribution, and visibility. Lesser studies were found, that describes the relation of human behaviour, mood and different light parameters. Nowadays in architecture and in several other fields, human scale and human centeredness has been coming into focus, just as in lighting design profession as well. This report aimed to research and find the factors of public lighting, that have a pleasing and enticing effect on humans, since the overall Lighting Metropolis project was about to generate social activity through lighting. Accordingly, a problem statement has been developed, and read as follows:

“Public spaces in Hyldebjerg are scarcely used in the night time by the local residents in lack of appropriate lighting”

The word “appropriate” covers all the factors that were aimed to be found out. Two parameters, as requirements were given by Lighting Metropolis, interaction and innovation. As an answer to the problem statement, along the project requirements, a hypothesis has been developed, to define the final goal what the project aims to achieve with an appropriate lighting. It read as follows:

“A new lighting design with interactive and innovative elements generates social activity and interactions at night-time at public spaces, thus strengthens the local community.”

Several articles has been studied about outdoor lighting aesthetics, preferences, lighting and mood relations, and researches on how light can be a motivator for activity. As it was found, colours, contrast differences, orientation points, non-conventional placement, horizontal and vertical light distribution, interaction with the lighting, control / ownership over the lighting are the factors that induced positive reactions in test participants. These elements became sub-criteria of the design, and together they constitute the “leaning effect on users” main criteria.

The proposed design incorporates all the mentioned design parameters, and in contrast to several articles, this report translates them to a concrete solution plan, suited specifically for Hyldebjerg. Applying these parameters together to create a scenographic – aesthetical layer and embedding functional lighting into the same luminaire, creates a new way of public lighting. Outdoor lighting is not only about visibility and about being visible anymore. According to human centric thinking and planning nowadays, it has been shifting towards information

indication, and in the case of this proposal, it became a new tool of the social web, a media that is expected to provide opportunity for further social activities and interactions. Beyond functional street lighting and indication of different things, this design brings public lighting onto another level, where it is customizable and personal.

Therefore, criteria of innovation is fulfilled by the integration of street lighting functionality and extra social interaction inducer layer into one fixture, the façade LED bars. The support luminaires, mounted on the bottom of the mailboxes are also innovative in terms of placement. In the case of the playground area, innovation is the involvement of nature by light.

The overall leaning effect is believed to be achieved by applying and combining the findings about enticing outdoor light researches. Participants who observed the design in VR glasses confirmed that the proposal raises interest and in reality, it would invite them for a more thorough exploration. Along this feedback it is expected, that the design would extend outdoor activity possibilities and durations, and by that, would establish still closer social links among local residents.

Despite the fact, that this proposal has not been accepted due to political, financial and practical issues, and a drastic revision is required, it lives up to the initial requirements, fulfils the project goals and criteria, and delivers a comprehensive, argued, high quality design in itself.

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Appendix



Appendix 1. Harry Potter playground in Hyldespjældet



Appendix 2. Users and use of space at the playground



Appendix 3. A typical side street in Hyldespjældet



Appendix 4. current HPS street lamp in Hyldespjældet



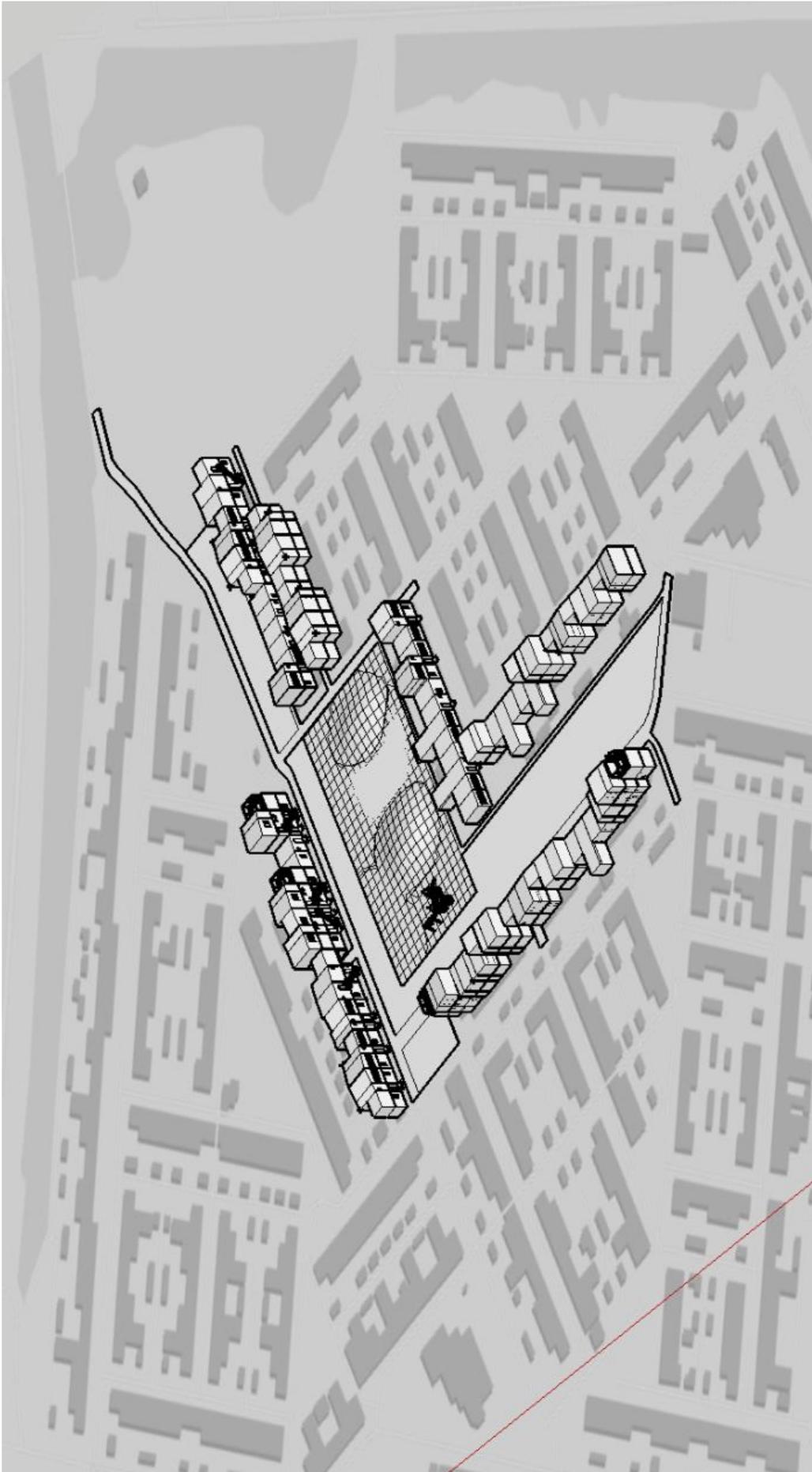
Appendix 5. Current visibility and street lighting in Hyldespjældet



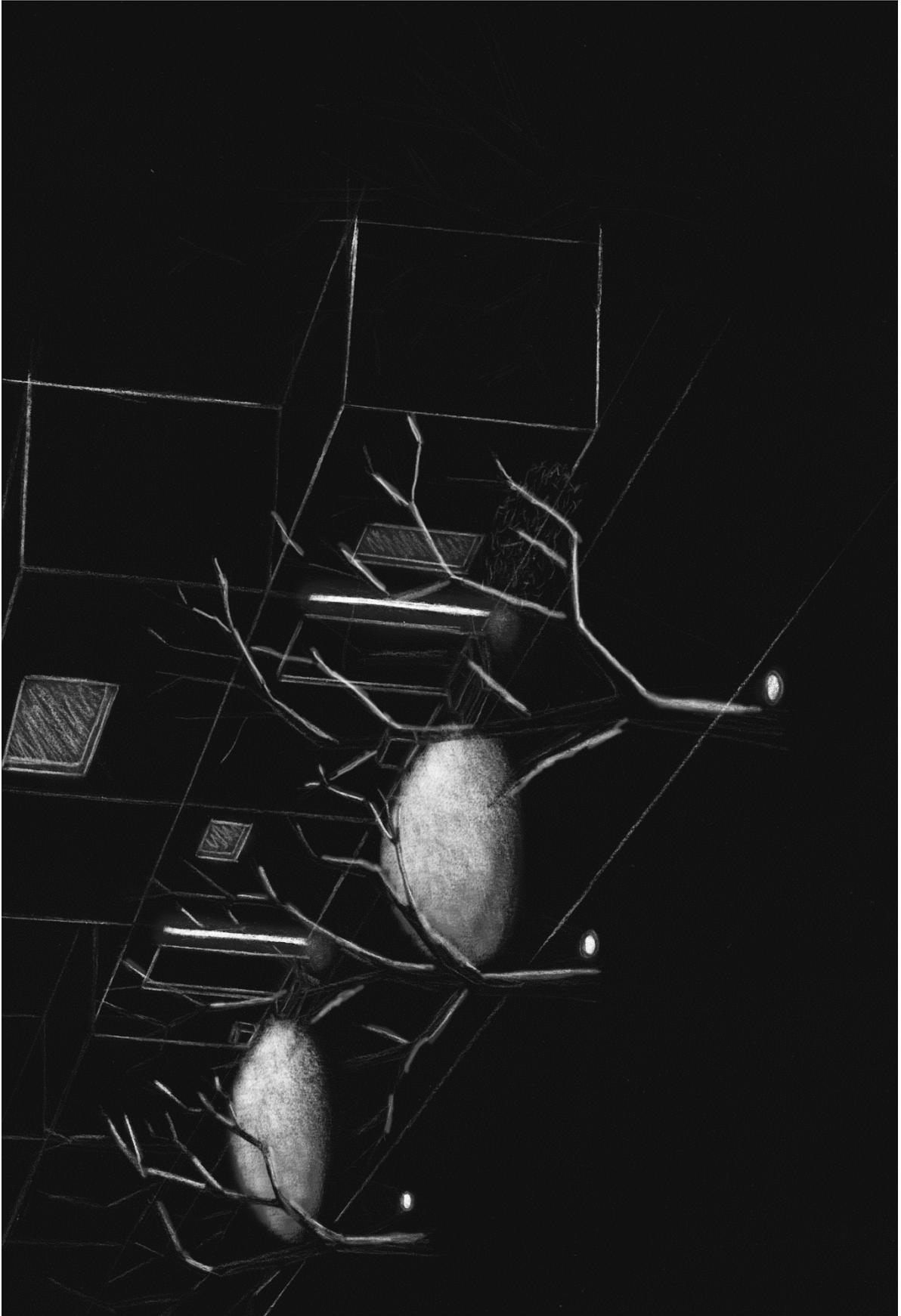
Appendix 6. Lux and spectral distribution measurement of a HPS streetlamp



Appendix 7. Lux measurement of a cool white LED street lamp



Appendix 8. Sketchup model of the demo area



Appendix 9. Hand sketch of the street lighting design



Appendix 10. Lit stepping stones – reference installation



Appendix 11. Updated 3DS Max model of the demo area



Appendix 12. Test renderings of the proposed design



Appendix 13. Visualization of the proposal in a side street



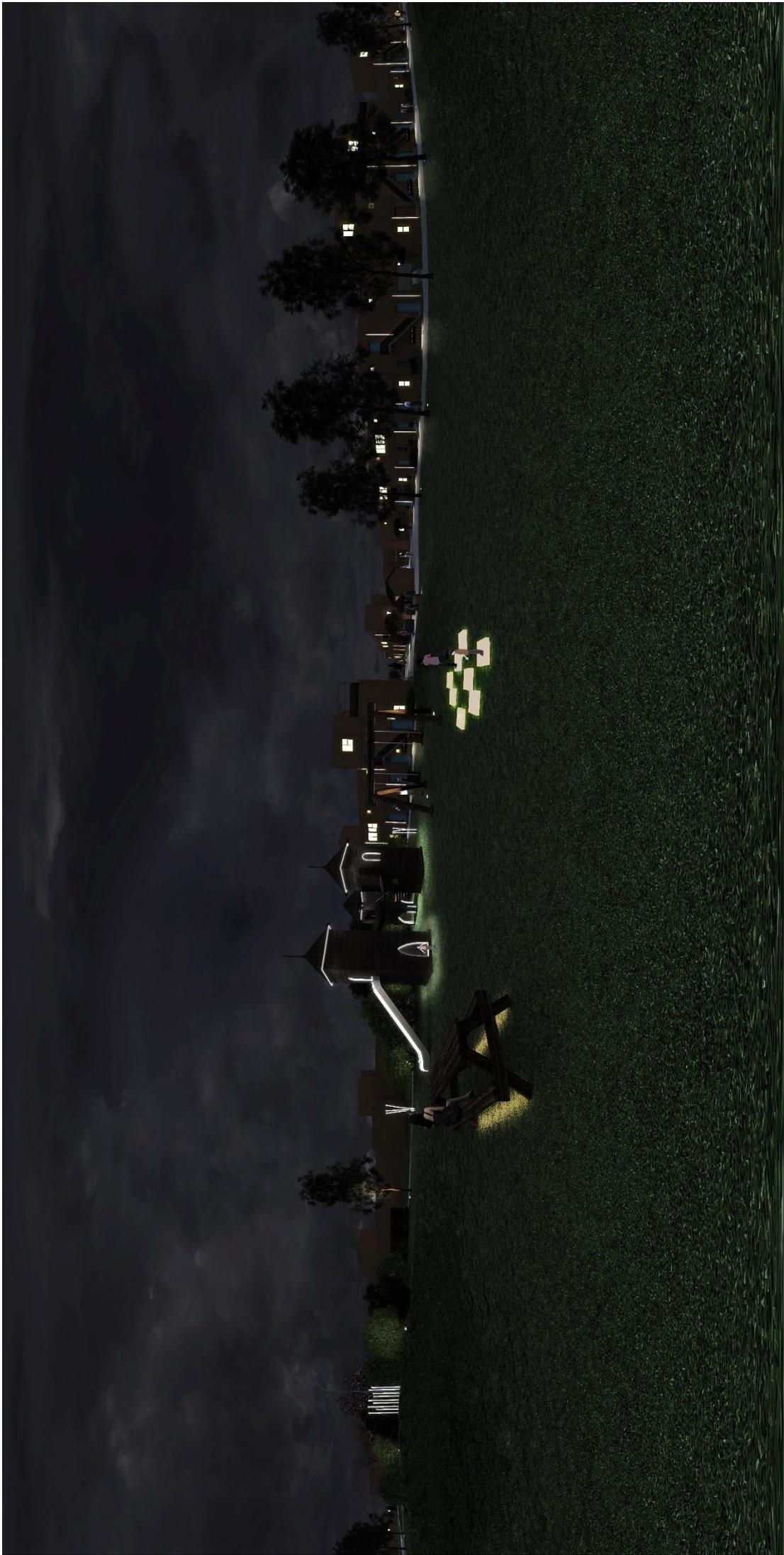
Appendix 14. Visualization of the proposed design 1



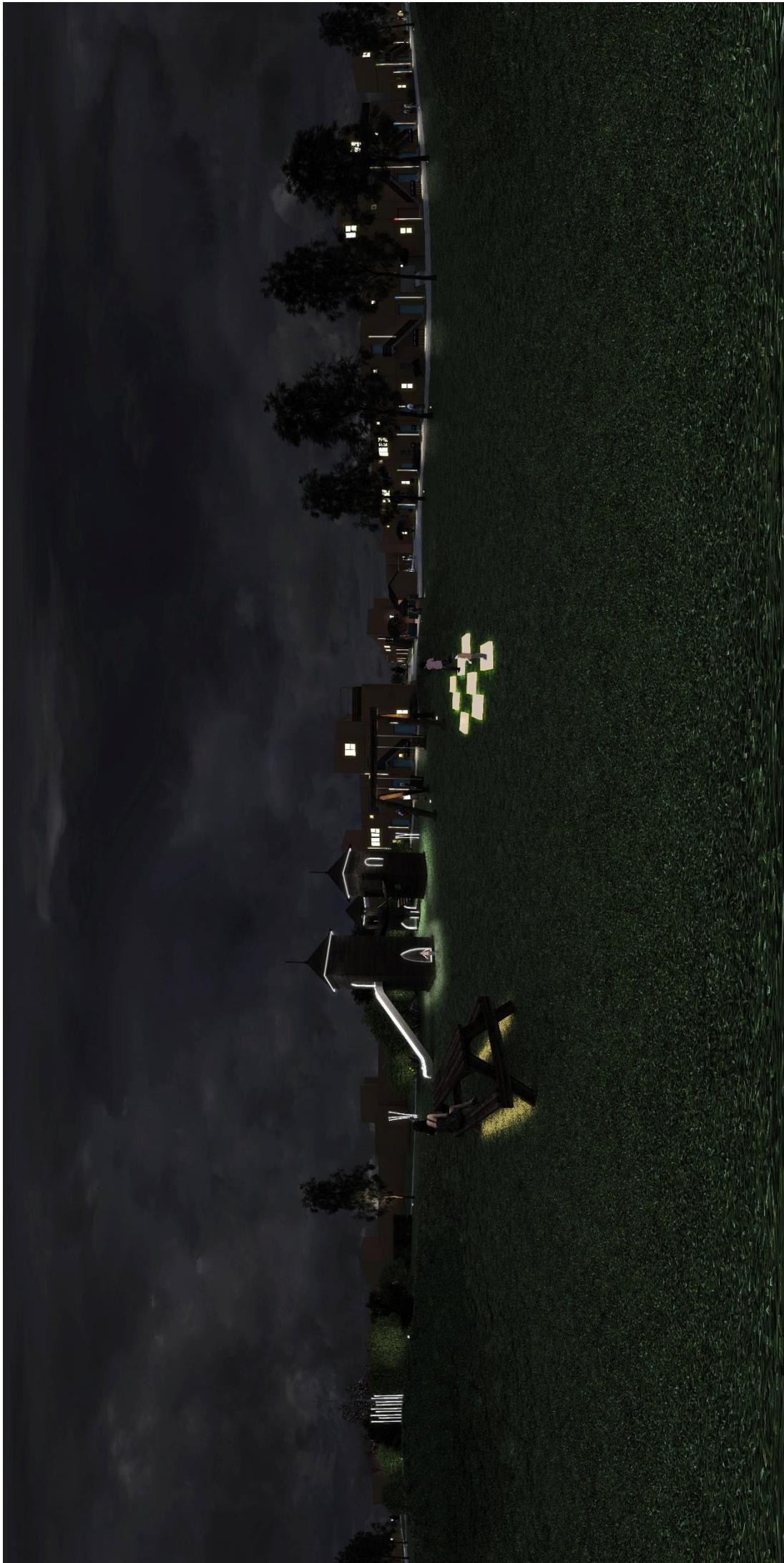
Appendix 15 . Visualization of the proposed design 2



Appendix 16 . Visualization of the proposed design 3



Appendix 17. Visualization of the proposed design 4



Appendix 18. Visualization of the proposed design 5



Appendix 19. Visualization of the proposed design 6



Appendix 20. Visualization of the proposed design 7





Appendix 22. Visualization of the proposed design 9