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Through a case study of Christiansholm

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Abstract:

This master thesis explores and investigates integrated lighting design as a specialised field in a design process rather than an added-on profession. Using trans-disciplinary scientific fields of architecture, light engineering and media technology, the aim is to confirm the initial problem statement as follows:

"By integrating lighting design in the early design process, it is possible to create an identity by improving the architectural qualities of a given space."

To confirm this statement, a case study has been selected in the competition phase known as Christiansholm, which will work as an investigation of the possibilities that lighting design possesses when integrated as a part of the architecture. Utilising a combination of two framework models to define the path towards new knowledge based learning, the authors analyse the master plan and highlight two elements that can create an identity by improve the architectural qualities.

Using the process model, through means of transferring, translating, transforming and communicating knowledge, the authors have specified success criteria which resulted in preliminary design solutions that are tested in terms of hypotheses. Their output derives a final design which is communicated through a Light Plan and ultimately highlighting the advantages of integrated lighting design.

M.Sc. Lighting Design

Lighting Design in an Integrated Design Process

Through a case study of Christiansholm

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Reader's Guide

Citations

Citations are made using Harvard Style and will appear at the end of a sentence with the author or publisher and the year released.
Example: (Johnson, 2015).

In case of multiple citations from the same author, a letter will help differentiate alphabetically.
Example: (Johnson (a), 2015).

Citations are listed in the bibliography in an alphabetical order.

Chapter or section references

References to a specific chapter or section will appear in *grey italic*.
Example: As argued in Section *3.4 Investigations*

Introducing new concepts

The first time a new concept is introduced, it will appear in *italic*.
Example: Introducing *Problem Based Learning* known from Aalborg University.

Quotes

Quotes are written in *blue italic* between quotation marks.
Example: *"Nothing in the world is more simple and more cheap than making cities that provide better for people." - Jan Gehl.*

Translations

In case of a direct translation, the original text will follow inside the squared brackets.
Example: *"The square is of great importance for the Danish Government"* [Pladsen har en stor betydning for den danske regering.].

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Introduction

1 Introduction

The Danish building industry needs to make space for lighting designers. A bold statement but nonetheless in line with the recent study made by the innovative network Danish Light, which concluded that *"there is a major need for lighting designers"*. This statement coincides with the industry's long desire for a Nordic lighting design master program at a high international level (Behov for lysuddannelse i Danmark, 2012). The issue at hand is that a traditional procurement in a conventional building process invites a lighting designer after major decisions about the building and space are defined, which enforces the specialisation field as an added-on profession. The authors do not see this as an optimal solution and believe that the building environment can improve by integrating lighting design in the early stages of the design process. Ideally, Denmark can be using other forms of procurement for the building process, where the lighting designers are partnered with the engineers and the architects in an integrated design process. There are different types of contracts and agreements and it is not the aim of the thesis to specify each one. Instead, the authors will throughout the thesis provide a demonstration of why involving lighting designers at an earlier stage in the design process will strengthen the results.

1.1 First Generation of Lighting Designers

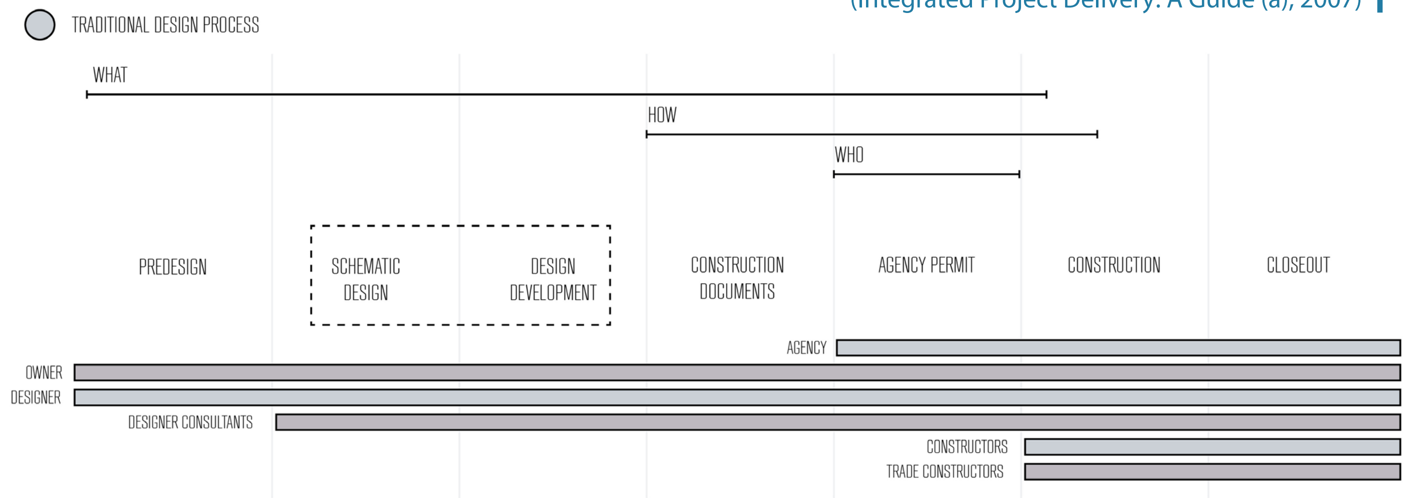
To meet this challenge, the first group of master's in lighting design will graduate from Aalborg University Copenhagen by summer of 2016. As the first generation of master's in lighting design in Denmark, it is important to highlight briefly that the master is a cross disciplinary program which integrates three scientific fields; architecture, light engineering and media technology. Previous projects conducted during this education include digital simulation of light through rendering, analysis and registration of lighting conditions, in-depth programming of interactive and intelligent lighting systems and development of scientific experiments with light. (Hansen and Mullins, 2014). Concerning the improvement of the building environment as mentioned in Chapter *1 Introduction*, it is the aim to highlight the strength of integrating a lighting designer in the design process who can communicate between the architects and the engineers, due to the trans-disciplinary master program. It should be noted that the thesis' authors come from two different backgrounds: Constructing Architecture and Medialogy.

1.2 Traditional versus Integrated Process

To understand how lighting design as a profession can be integrated earlier in the design process and how general project procurements work in Denmark, this section intends to touch upon a selection of building processes with focus on the design approach.

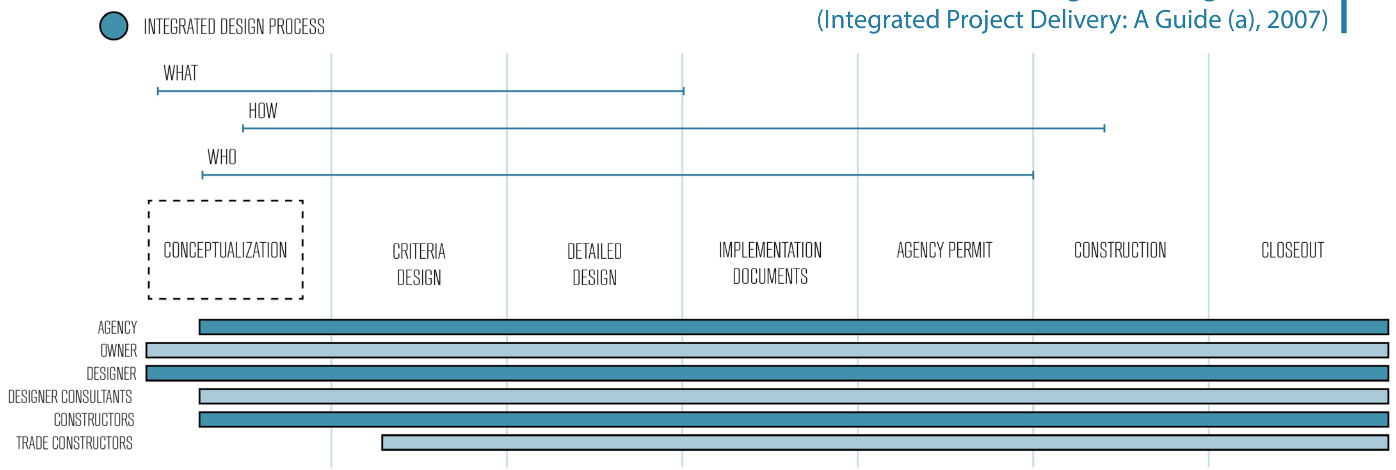
One of the most common project procurement processes used in Denmark is known as *Design-Build*, where one unit will carry out both the architectural design and construction under one contract (Design Build, 2010). Most commonly this unit is led by a contractor. The advantages of using Design-Build are that it is usually the fastest project delivery and the cost is established at a much earlier phase. As illustrated in Figure 1, a lighting designer will typically enter the project in between the *Schematic Design* phase and the *Design Development*, enclosed with a dashed square. By this stage in the building process, major decisions have been decided and a critical disadvantage of using this procurement is that making changes at a later phase are challenging and costly.

Figure 1
Traditional Design Process
(Integrated Project Delivery: A Guide (a), 2007)



In addition to this, the massive drawback lies in the fact that consultants such as architects and lighting designers do not have a direct contract with the client. This lack of a direct contract increases the risk of whom watches out for the owner's interest and the quality of the final project. This issue can be solved by using the integrated design process which is highly popular in the United States. Commonly known as *Integrated Project Delivery*, the procurement process is defined as a method of delivering a project design that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction (Integrated Project Delivery: A Guide (b), 2007). As Figure 2 shows, a lighting designer will enter the project in the *Conceptualization* phase, enclosed with a dashed square, which is identical to the *Predesign* phase in Figure 1. At this phase, the questions of *what*, *how* and *who* are defined. That is where the responsibilities of each party are determined and signed into one form of agreement. The master thesis aims towards using Integrated Project Delivery as a reference model to project procurement, where a case study will be presented to define reasons as to why it is important that lighting designers are a part of an integrated project.

Figure 2
Integrated Design Process
(Integrated Project Delivery: A Guide (a), 2007)



1.3 Intelligent versus Interactive Lighting Design

In Section *1.1 First Generation of Lighting Designers*, it was stated how master's in lighting design are capable of communicating with the architects and engineers. Another strength of having a lighting designer early in the design process is their ability to integrate *intelligent* and *interactive* systems. Through this integration it is possible to apply performance variations based on information gathered from specific events such as the surrounding environment, natural phenomenon, user interaction, etc. This competence derives from media technology, being the third scientific field in the trans-disciplinary master program. The difference between an intelligent system and an interactive system lies in the means of information gathering as described below.

Intelligent

An intelligent system is a machine with an embedded computer that can gather and analyse data and communicate with other systems (WhatIs.com, 2016). An example could be a system which changes the colour of a light source with ten-minute intervals by receiving information from a connected timer. Including an intelligent system in the lighting design makes it possible to create more complex designs, that result in unique experiences. Additionally, it allows for a more site-specific design, where it is possible to take the behaviour and changes of the surroundings into consideration.

Interactive

An interactive system is a computer system characterised by a significant amount of human-computer interaction (Encyclopedia.com, 2016). An example could be a system with a light source which increases its brightness based on human movement by receiving information observed from a thermal camera. Including an interactive system allows the audience to be an active part of the lighting design. Possibilities like playing with the light and the experience of their impact have a strong effect of creating an immersive environment. However, it is important that the interaction is intelligible both regarding to human interaction required to perform, as well as the responding change in the light.

To be able to implement a successful intelligent or interactive system, it is important to have an in-depth knowledge of the appropriate hardware, as well as an understanding of the functions of the associated software.

1.4 Initial Problem Statement

Acknowledging the information presented in Chapter *1 Introduction* and its Sections *1.1-1.3*, it is the aim to provide a demonstration of why integrating lighting designers in the early stage of the design process will strengthen the possibilities of creating an identity and improving the architectural qualities of a given space. This is investigated by using the scientific fields of architecture, light engineering and media technology in a trans-disciplinary approach. Henceforth, the formulated initial problem statement:

"By integrating lighting design in the early design process, it is possible to create an identity by improving the architectural qualities of a given space."

By answering the initial problem statement, it is expected to validate that implementing lighting design in the early design process will create an identity by improving the architectural qualities of a space. To confirm the initial problem statement, a case study in the competition phase was selected which is equivalent to the Conceptualization phase of Integrated Project Delivery as explained in Section *1.2 Traditional versus Integrated Lighting Design* and illustrated on Figure 2. The case study will work as an investigation of the possibilities that lighting design possesses when integrated as a part of the architecture.

Chapter 2

Case Study Christiansholm

2 Case Study Christiansholm

As explained in Section *1.4 Initial Problem Statement*, a case study is selected to confirm the initial problem statement. The case study is known as *Christiansholm*, an Island in the harbour of Copenhagen. The reason for choosing this particular case study is because the lighting design has not yet been integrated as part of the project's design process and thus, the authors want to investigate the lighting design's possibility of creating an identity by improving the architectural qualities of Christiansholm. To the majority of Copenhageners, the space is recognised as the Paper Island [Papirøen]. The prior tenant of Christiansholm, The Danish Press Joint Purchase Association [Den Danske Presses Fællesindkøbsforening] used the island as storage for paper, hence the affiliated name Paper Island. In December 2011, they decided to terminate their lease as paper storage halls, seven years earlier than their original contract duration which could have lasted until 2018.

CPH City & Port Development [By og Havn] is the owner of the land while Klaus Kastbjerg, the CEO of Union Holding A/S owns the buildings (København er på vej..., 2016). At the time of purchase, the island was closed to the public and it was Klaus Kastbjerg's decision to begin renting the industrial halls on a temporary basis for different functions like Copenhagen Street Food, Experimentarium, art galleries and fashion shows, etc. Klaus Kastbjerg's aim was to make the area accessible to the public and to create awareness of the island's potential (Masterplan Christiansholm - Dommerbetænkning (a), 2016). With the island becoming a public attraction, the landowner called for a competition of gentrifying the Paper Island to a new neighbourhood to be known as Christiansholm starting in 2018.

The architectural competition was hosted by CPH City & Port Development and it began on the 5th October, 2015. Seven architecture firms were invited to participate, each with a team of consultants ranging from engineering and landscape companies to communication associations. Each team was assigned to develop a thorough Master Plan to find the best possible solutions for the 29.000 m² large island with a maximum of 45.000 m² buildable floor space. It was a requirement to have public areas included. The deadline was on the 7th December, 2015 while the announcement of the winner took place on the 11th February, 2016 (Masterplan Christiansholm - Indbudt Projektkonkurrence (a), 2015). It was a common desire conveyed by the seven architecture teams in the competition phase to reinforce the identity of the space by maintaining existing structures while creating new facilities which support similar activities of those found today. The winner of the competition, the architecture team led by COBE, has enforced this concept with the idea of providing multifunctional halls which can create a greater proximity between diverse functions to achieve a greater synergy

(Cobe.dk (a), 2016). There is an understanding of scale while they characterise the development as "*blue on the outside*" and "*green on the inside*", which will be further analysed in Section *4.1 COBE's Master Plan.* The two characteristics are illustrated in Figure 3 and 4.

Christiansholm occupies a central place in the harbour of Copenhagen and together with the winning Master Plan, the authors of this thesis saw a growing potential for a master project because the development will serve as a new urban fabric for the capital city. Having visited the area, which currently consist of grey industrial halls, this is an excellent space with a unique identity. One that has the potential of stretching the social and cultural interactions of people while providing opportunities for living in the heart of the harbour.

Looking towards the goal of confirming the initial problem statement, the case of Christiansholm has multiple advantages as stated at the beginning of this section. Additionally, it is a substantial project which offers a realistic verification of the initial problem statement compared to a fictional case study.

Figure 3
Blue on the outside
(COBE (a), 2016)

Figure 4
Green on the inside
(COBE (b), 2016)

Chapter 3

Method

3 Method

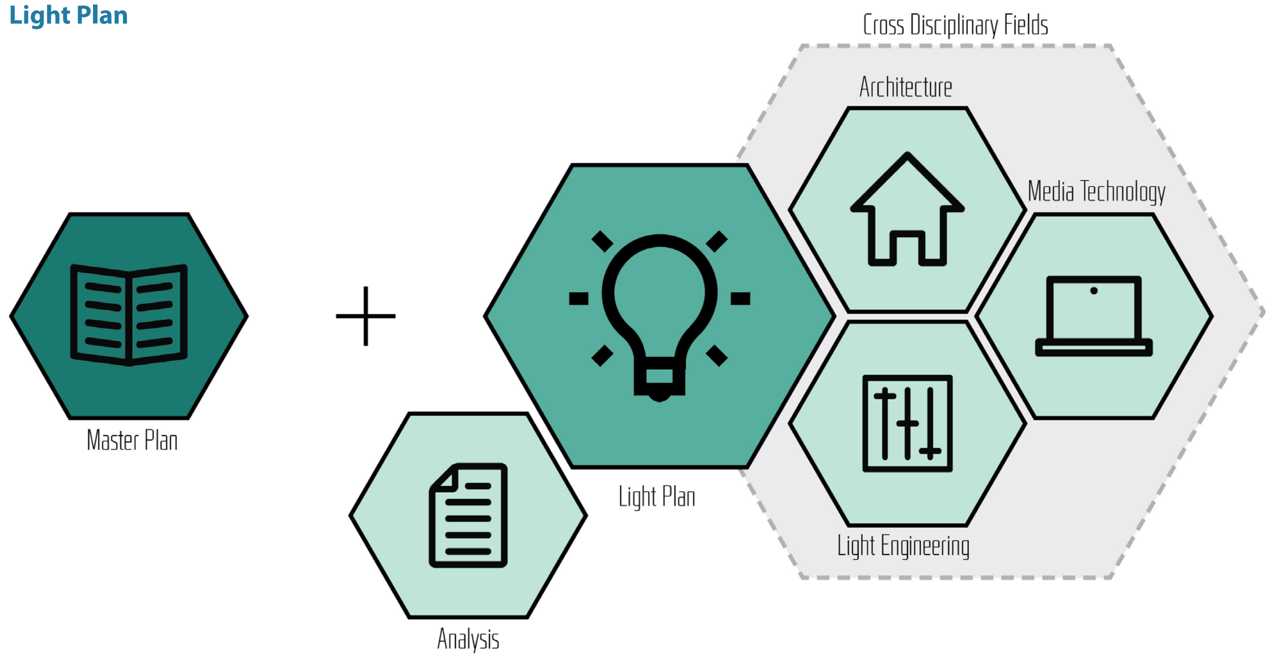
The methodology for this master thesis is defined by the following models that were used to achieve a holistic design approach of combining the scientific fields of architecture, light engineering and media technology. Section *3.1 Light Plan* defines the knowledge used in this thesis to achieve a *Light Plan* that coincides with the case study and the trans-disciplinary fields. Subsequently, Section *3.2 Process Model* depicts the strategic combination of two framework models that define the path towards new knowledge based learning and will be referred to as the *process model*.

3.1 Light Plan

A Light Plan can be described as a plan view of a space illustrating the light, which is used to communicate the intentions for the lighting design to other parties involved like the architects and engineers. In spite of that, the authors define a Light Plan as an assembly of drawings from floor plans to sections and renderings, used as a communicative tool for the functional and the aesthetic values of the lighting concept demonstrating the different layers of light. This Light Plan can illustrate the necessary involvement of early integration by creating an identity and improving the architectural qualities of a given space, as the problem statement in Section *1.4 Initial Problem Statement* specified.

To accomplish the Light Plan, Figure 5 has been developed, where it highlights the necessary knowledge required. When analysing the material delivered by COBE, there is no sign of a Light Plan. The authors thus want to investigate the potentials of being involved in a project at such an early phase and the advantages of developing a Light Plan before major decisions are defined. The *Master Plan* in the figure refers to the case study, which is the critical backbone that the Light Plan will be added to and explains the architectural choices to be realised. To produce a Light Plan, the analysis in Section *4.2 Elements of Christiansholm* will be combined with the cross disciplinary fields marked inside the grey region. The success of this model will be defined by the outcome of the Light Plan.

Figure 5
Light Plan



3.2 Process Model

As a framework for the thesis, a process model has been developed, which combines *problem-based learning* and *the architectural experiment*, which synthesises with technical, creative and humanistic methods (En.aau.dk, 2016), (Hansen and Mullins, 2014). Figure 6 illustrates the process model and each stage in the model is a step towards gaining new explicit knowledge in the form of a Light Plan and confirming the initial problem statement. The headlines above the circles refer to the problem-based learning pedagogical model from Aalborg University that has become internationally recognised as an advanced learning prototype (En.aau.dk, 2016). Inside the circles, the steps represent the stages of the architectural experiment. The model provides the possibility of working analytically across disciplinary fields which in this case, refers to architecture, light engineering and media technology. It attempts to resolve the questions first formulated of how knowledge of different disciplines can be thoroughly integrated into the design process, create innovative solutions and generate new explicit knowledge (Hansen and Mullins, 2014).

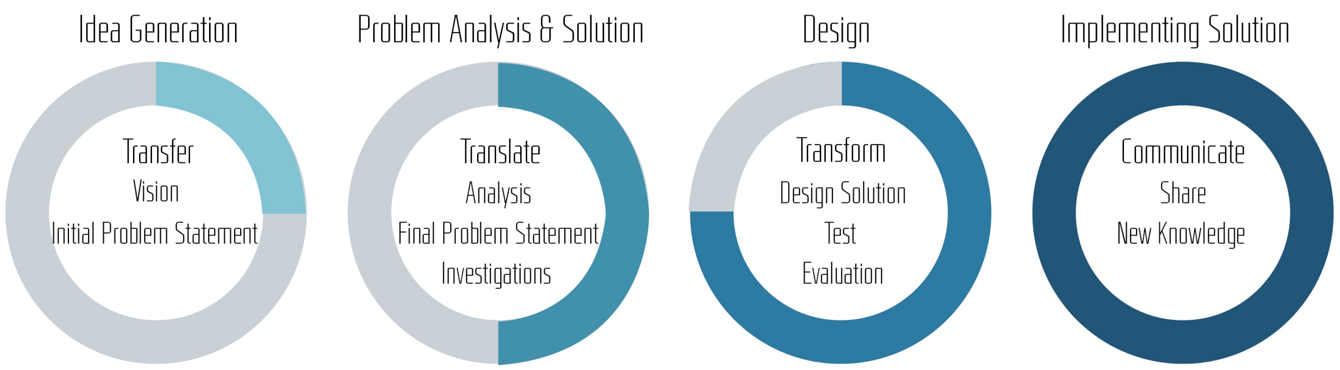


Figure 6
Process Model

The first stage, referred as *Idea Generation*, is about transferring knowledge from different disciplines where a mutual vision is created for the project. Coinciding with this stage, a problem to be solved has been defined; the output is the initial problem statement as presented in Section *1.4 Initial Problem Statement* being:

"By integrating lighting design in the early design process, it is possible to create an identity by improving the architectural qualities of a given space".

The second stage, *Problem Analysis and Solution*, is about translating knowledge and unfolding the initial problem statement into defined criteria which will attempt to provide a solution. Thus, the authors will first analyse COBE's Master Plan which leads to specifying elements that are important in defining the identity and to support the lighting design. The output of this stage is a formulation of the final problem statement which relates to the architectural qualities of Christiansholm. Additionally, this output will include contemporary projects as means of comparing and contrasting existing lighting designs related to the elements which further set specific design criteria to be achieved.

The third stage, *Design*, is about transforming and evaluating knowledge. The specific design criteria are resolved into preliminary design solutions after challenges have been set to meet the needs of the users. Preliminary designs are tested to improve the design and meet the success criteria. The output of this stage is the evaluation, which assesses and combines the ability to answer the final problem statement.

The fourth and final stage, *Implementing Solution*, is about communicating and sharing the new knowledge.

Chapter 4

Analysis

4 Analysis

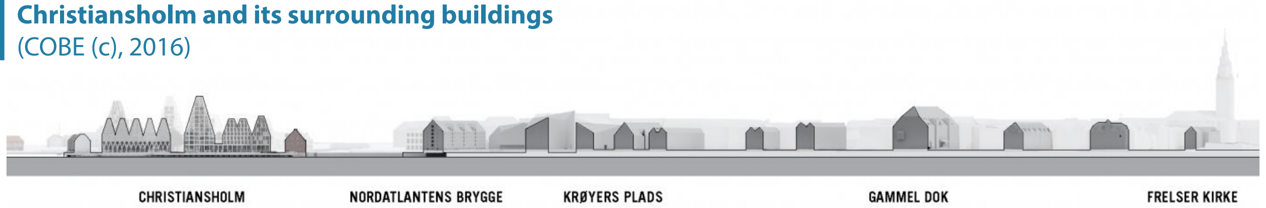
This chapter begins by analysing the Master Plan alongside investigations, where the main elements to be used in the Light Plan will be highlighted. This analysis leads to a final problem statement. The chapter covers a variety of investigations and corresponds to stage two in the process model, problem analysis & solving, on Figure 6 in Section *3.2 Process Model*, where it is necessary to translate knowledge by unfolding the final problem statement and gather the observations needed for the design during problem analysis and investigations. To answer the final problem statement, investigations of existing lighting designs are conducted to draw experiences and knowledge from previous projects, which relate to the different spaces of Christiansholm. The studies will ultimately lead to influences and specific success criteria which will be used in the design phase.

4.1 COBE's Master Plan

Of the seven teams participating in the competition, the team led by COBE with assistance from Inside Outside, Via Trafik Rådgivning and Transsolar Energietechnik were determined as the winners. When comparing the seven proposals to each other, it was evident why COBE was the clear winner of the competition. Their project defines a clear link between the surrounding buildings and those to be allocated in the future of Christiansholm, as illustrated in Figure 7. Their approach is adaptability to the local context, its social life and its users (Cobe.dk (b), 2016). Among the comments given by the judges committee was the following:

> "*Not only did they deliver a clear analysis of the tasks and the place's uniqueness, but as the only team in the competition, they managed to transform words into structure and shape it in a way that convinced the judges that the basis for Christiansholms future development is a dense and experience full city neighbourhood with special site-specific character, which was one of the competitions goals to achieve.*" [Forslag 5 er ikke ene om at levere en klar analyse af opgavens og stedets særlighed, men som konkurrencens eneste magter forslagsstillerne at omsætte ord til struktur og form på en måde, der har overbevist dommerkomitéen om, at grundlaget for Papirøens fremtidige udvikling til et tæt og oplevelsesrigt bykvarter med den særlige stedsspecifikke karakter, der er et af konkurrencens mål, er til stede her.] (Masterplan Christiansholm - Dommerbetænkning (b), 2016).

Figure 7
Christiansholm and its surrounding buildings
(COBE (c), 2016)

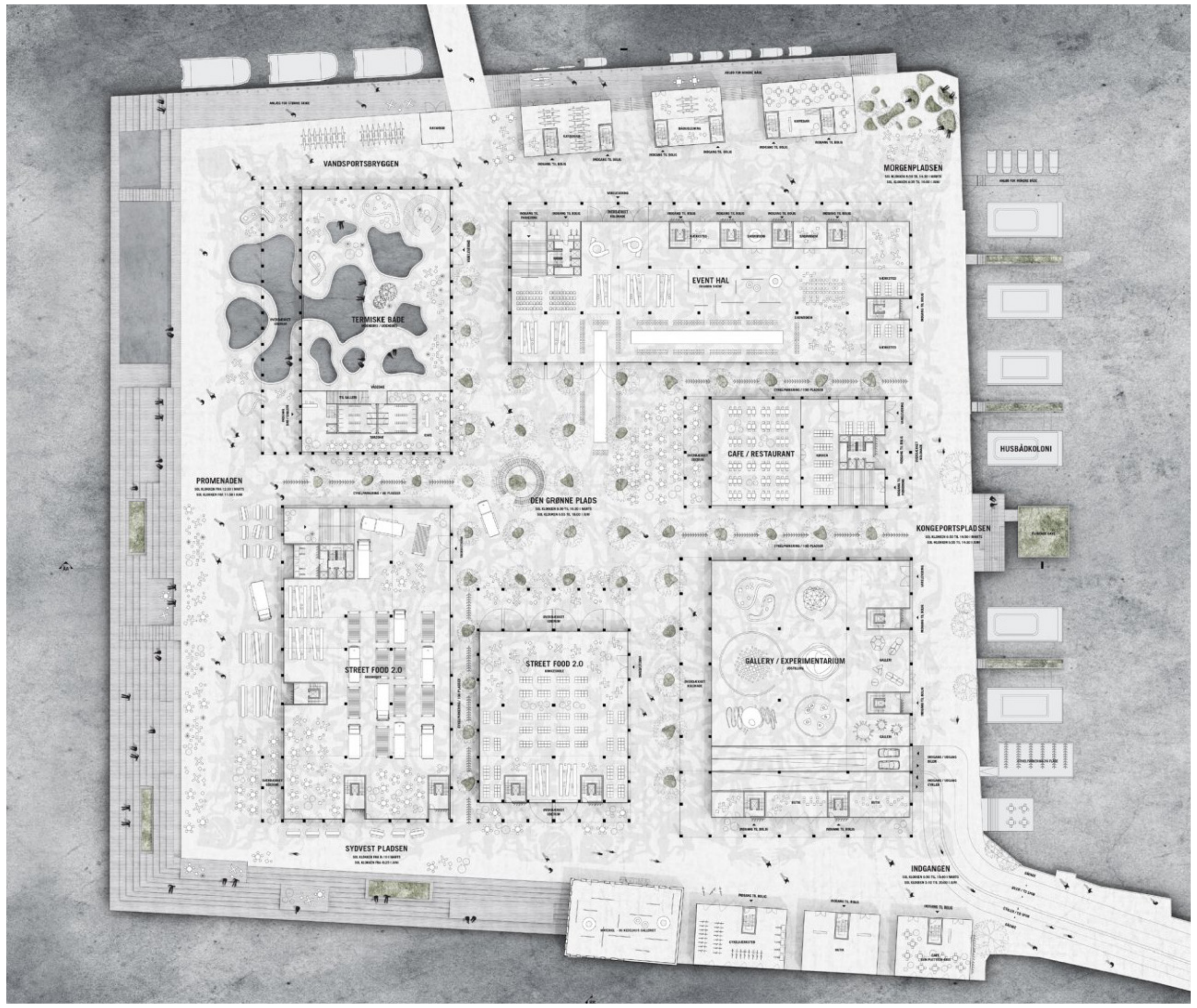


The "*special site-specific character*" the judges committee refers to in the comment is what the authors seek to support through the initial problem statement of creating an identity and improving the architectural quality of the space.

The winning concept includes residential areas, indoor and outdoor swimming hall facilities, event halls for possible art galleries, fashion shows, Copenhagen Street Food, Experimentarium, etc. as well as a shared garden in the centre. COBE characterises the development as blue on the outside and green on the inside, which will be referred to as *blue exterior* and *green interior*, respectively, throughout the thesis.

The term blue exterior refers to the promenade which surrounds Christiansholm. The water and the experience it brings are important elements in the development of the city's recreational potential (Det grønne København - parkpolitik 2003 (a), 2003). These elements are utilised by providing an outdoor bath, houseboats, kayak facilities and mooring for smaller boats. The blue exterior helps to attract visitors to visit Christiansholm with its great exposure throughout the promenade with iconic surrounding buildings like the Royal Danish Playhouse [Skuespillerhuset] and Copenhagen Opera House [Operaen] as well as the old neighbourhood Christianshavn. A floor plan of the blue exterior is illustrated on Figure 8.

Figure 8
Blue exterior floor plan
(COBE (d), 2016)



The term green interior refers to the centre of the island, which aims to be a luscious green haven. This green connection is part of the very essence and identity of being a Copenhagener as all city dwellings have inner courtyards with green landscapes or are surrounded by green districts. One of the visions that the municipality of Copenhagen had for 2015 was that 90% of Copenhageners can go to a park, a beach or a promenade in less than 15 minutes (Lommeparker, træer og andet grønt, 2008). Historically seen, this is a natural transition from the fortified city, through the industrial development towards the Finger Plan, which has affected the development of Copenhagen's park structure (Det grønne København - parkpolitik 2003 (a), 2003). In Christiansholm, the garden on the ground floor is open to the general public while the residents of Christiansholm will have privately shared rooftop gardens above the industrial halls. This green centre aims to gather all the buildings into one shared meeting point where you can enjoy your food, attended a flea market or drink a refreshment with your friends and neighbours. A floorplan of the green interior is illustrated on Figure 9.

Thus, the authors see COBE's decision to provide a blue promenade which surrounds the island and a green inner courtyard as a wise choice which can benefit both residents and visitors of Christiansholm.

Figure 9
Green Interior Floor Plan
(COBE (e), 2016)

Based on the acknowledgements from the judges committee, it is a vision to develop a Light Plan with a distinct lighting design identity that emphasises the ideology of creating an experience full city neighbourhood that identifies with Copenhagen. In addition to this, the lighting should improve the diversity of the environment and accentuate the Danish nature that is introduced to Christiansholm with the concepts of being blue on the outside and green on the inside. The realisation of these spaces will be further elaborated in the following section.

4.2 Elements of Christiansholm

As a result of the analysis derived from COBE's Master Plan, the elements to highlight through lighting design are the blue exterior and the green interior. The blue and green elements will create an identity for the island by improving the architectural qualities. Before generating inspiration, it was important to scrutinise the significance of these two spaces and in this manner, Figure 10 has been developed where a summary of findings is gathered to emphasise their calibre.

Figure 10
Elements of Christiansholm

Question	Blue	Green
Why is this area important?	- Copenhagen's harbour history - Success of Islands Brygge - Recreational potential of water	- Copenhagen's inner courtyards - City's urban fabric - Green identity
Which functions does this area possess?	- Eye-catcher - Active space - Water communication	- Intimate zones - Room for events/activities - Seasonal change
What are the light potentials in this area?	- Communication to surroundings - Intelligent/Interactive - Use of wind and water	- Intimate light zones - Flexible solutions - Use of vegetation
Is this area more public or private?	- More public	- More private
Who can see the light in this area?	- Residents - Visitors - Neighbouring surroundings	- Residents - Visitors

4.2.1 Blue Identity

The blue space is an essential element to be associated with Christiansholm because it signifies the distinct quality of Copenhagen’s clean harbour. The harbour and its baths are a stunning urban oasis that marks Copenhagen’s position as a clean, livable city and one of the most sustainable capitals in the world. Back in 2002, a public harbour bath opened in the area of Islands Brygge and it is now one of the most popular spots in Copenhagen during warmer seasons for both residents and tourists (Dac.dk, 2016). There is a massive recreational potential with water as an essential element and the geographical position of Christiansholm is a pearl gem in Copenhagen. The blue space possesses an eye-catching, active area with possibilities for activities like indoor and outdoor swimming, callisthenics, yoga, etc. The surrounding water is a strong communicational tool which coincides with the light potentials of the space. Furthermore, the buildings and the space serve as a communicator to the neighbouring surroundings and allows for possible intelligent or interactive lighting system. The blue space is more public compared to the green space and invites nearby areas amongst residents and visitors to see the light.

4.2.2 Green Identity

The green space is an element of Christiansholm which identifies with the inner courtyard city structure of Copenhagen. Take a look at Copenhagen from a satellite view and suddenly you will have an understanding of the city’s urban fabric. The green identity provides areas of great significance to the inhabitants of the local communities, accommodating a pleasant place to pass through or an essential component of the view from their window. This hierarchy of parks forms a mosaic which is to be maintained and developed (Det grønne København - parkpolitik 2003 (b), 2003). Functionally, the green space possesses intimate areas with room for events and activities. Due to the vegetation, there is a better sense and understanding of seasonal change which coincides with the light potential on the space. The green space is surrounded by building structures and is therefore more private compared to the blue space. It primarily invites the residents living on the island and curious visitors.

4.2.3 Expanding the Blue and Green

To generate inspiration for the lighting design of the blue exterior and green interior, the pedagogical method of a *word association approach* workshop was executed (Entreprenørskabsskolen, 2011). The technique aims to lower restrictions in the thought process and allows for a wider range of ideas. The method resulted in a compilation of two mood boards that were generated to visualise the emotions that the lighting design should synthesise. The blue mood board is illustrated on Figure 11. The associations for the blue exterior are primarily focused on the surrounding water and its many different uses and expressions; the therapeutic sound of waves, the creatures that live underneath, the vast playground if you are in a kayak. Most importantly are the light reflections, where the different weather conditions change the colour and movement in the water.

Figure 11
Blue mood board
(Bridge, 2016), (Ultralinx (a), 2016), (Felix CG, 2016), (Betty, 2016), (Canoe & Kayak, 2016), (Brommel, 2016), (Kasuga, 2016), (Ultralinx (b), 2016), (Oracle Fox, 2016).

The green mood board is visualised in Figure 12. The associations are mostly targeting trees and vegetation and the general understanding of nature's seasonal transition. Additionally, it is an aspiration to incorporate the Danish tradition of *hygge* by creating intimate areas where users can relax in, meet friends, have a picnic, etc.

Figure 12
Green mood board
(Coquita, 2016), (Red Bubble, 2016), (Rosselli, 2016), (Adamus, 2016), (Dwell, 2016), (Ganref, 2016), (Bylife, 2016), (Succulent Centerpieces, 2016), (Adventures in Cooking, 2016)

During this approach, inspiration from the mythical island of *Atlantis*, combining the blue and green elements has come to attention as illustrated on Figure 13. One must understand that it is not the intention to define or transform Christiansholm into Atlantis, but instead, use it as a source of inspiration that can be utilised in a concept based lighting design.

Atlantis

The story of the mythical island Atlantis dates back to the ancient Greek philosopher Plato, who was born more than 400 years before Christ (Denstoredanske.dk, 2016). Plato narrates that Atlantis should have disappeared from the water surface 10.000 years before Christ. The island is anticipated to be a myth as Plato's writings are the only records of its existence. Thus, it is likely that Plato invented Atlantis to emphasise his idea of an ideal society (Atlantis, 2016).

Figure 13
Atlantis
(Glasson, N., 2015)

The story of Atlantis has been chosen as an inspirational concept for multiple reasons. Looking into the comparisons of Atlantis and Christiansholm, the authors drew many parallels. Firstly, Atlantis being an island hidden below the water surface, it has always been a mythical inquiry whether it someday reappears above the water surface. This ideology fits well with Christiansholm, which after its gentrification will appear as an entirely new island in Copenhagen, as if it rose above the water surface for the very first time. Secondly, when investigating the tales of Atlantis, theories suggested that it consisted of mighty circular rivers with a palace in the centre as illustrated on Figure 13. This analogy is similar to that of Christiansholm, with the blue exterior symbolising the mighty circular rivers and the green interior with a lush haven in the centre, as the palace of Christiansholm. With these associations in mind, Atlantis is used as an inspiration to highlight the differences between the blue exterior and the green interior.

4.3 Final Problem Statement

To verify the initial problem statement and acknowledging the information presented in Section *4.2 Elements of Christiansholm* on Figure 10, the identity of the blue and the green elements are defined. The identity of the blue is described as a public and active space which has light potentials of communicating with its surrounding through water. The identity of the green is a more private and intimate space which has light possibilities of using the vegetation to communicate seasonal change. The final problem statement has been developed on behalf of the Master Plan from COBE with focus on the blue promenade and the green hall:

"Implementing a Light Plan coinciding with the Master Plan can improve the identity of blue promenade and the green hall."

It is expected to confirm the final problem statement by developing a Light Plan that coincides with the Master Plan, which demonstrates how integrated lighting design can improve the identity of the blue promenade and green hall. To derive influences and specific criteria which can improve the design in the Light Plan, investigations on a selection of contemporary projects took place, which will be further elaborated in the following section.

4.4 Investigations

The following section gives an insight to the projects used as inspiration for the Light Plan of Christiansholm. It should be noted that these works were chosen carefully on behalf of their high quality in one or more of the three scientific disciplinary fields; architecture, light engineering and media technology. Moreover, the chosen projects were all selected as they have distinct parameters that draw parallels to either the blue exterior or the green interior. The following subsections will explain the strengths and weaknesses analysed from a variety of projects as well as explaining the influence they will have on the Light Plan. This section coincides with stage two, in the process model on Figure 6 explained in Section *3.2 Process Model*, where it is necessary to translate knowledge by unfolding the final problem statement and gather the observations needed for the design during problem analysis and investigations.

Blue Exterior

4.4.1 Wintergarden by Studio 505

In the Australian city, Brisbane, the facade of Wintergarden Shopping Centre has been transformed to give an engaging retail experience (Studio505.com.au, 2016). Its view from three street sides in the city centre, is an eye-catcher both during daytime and nighttime. The facade is constructed as a complex structure which aims not to be an illustration of nature nor a merely abstract pattern. The multiple layers and patterns on the facade construction takes inspiration from various natural elements, such as treetops, fish shoals and butterflies. The facade can be associated with a forest but the different materials and colours provide an abstract appearance which attests to discovering new elements repeatedly. The structure, as well as its materials and colours, have been chosen in order to generate different shadows and patterns, depending on the different position of the sun throughout the day and seasons. The interplay with the daylight complements the abstract element of discovering new details each time you visit the shopping mall (Studio505.com.au, 2016). During the nighttime when there is no sunlight, the facade is lit indirectly by 24.000 LEDs (Jackson et al., 2015). The indirect light is programmable and generates different patterns from seasonal weather changes to fireworks. The light at night creates an entirely different facade with a new expression. That said, the results seems very commercial and mundane. The facade is transformed from a beautiful and interesting surface throughout the day, into a big screen media facade. It is a shame that the construction has not been utilised at nighttime to narrate stories about the forest that is so engaging during the daytime. Figures of the Wintergarden Shopping Center can be seen during daytime on Figure 14 and nighttime on Figure 15.

Figure 14
Wintergarden at daytime
(Studio 505, 2016)

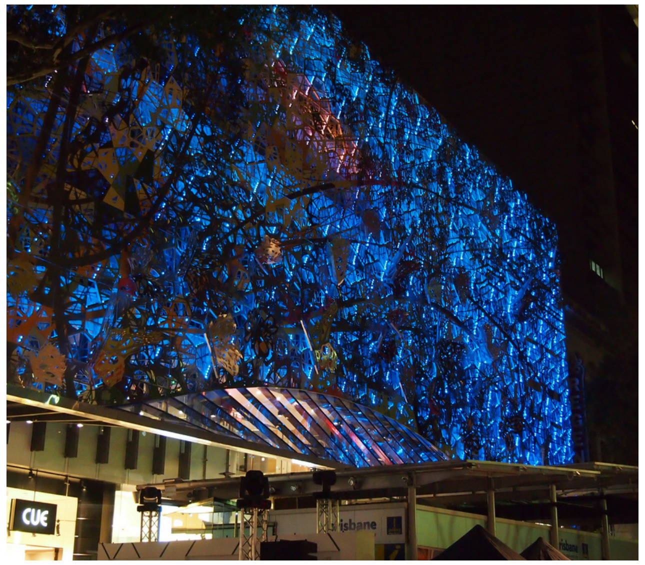


Figure 15
Wintergarden at nightime
(Wintergarden Facade Nighttime, 2016)

4.4.2 L'Ö by Yann Kersalé

In similar context to Christiansholm, The Quai Branly Museum in Paris has a light project combining water and vegetation. The lighting designer, Yann Kersalé collaborated with Jean Nouvel and Gilles Clément on a fictional lake which consisted of 1.600 translucent rods that change colour in response to the temperature recorded by a weather station. The project is titled "L'Ö", a pun for water which glimmers in the midst of the garden when darkness has set and the museum's garden is shut. Yann Kersalé explains the project as:

> *"A water of light evaporates from the glass stems, of which the white colours from blue to green are guided by a digital thermometer."* (Kersalé, 2006).

The designs ability to express water through light delivers strong inspiration for the blue exterior of Christiansholm. The lighting design has a substantial connection to the surroundings being placed inside the vegetation and reflecting onto the construction above. It communicates a story about the evaporating water. The narrative is strengthened by implementing a colour palette with blue and green colours connecting the lighting design to the surroundings. The colours are dependent on an intelligent system which translates temperature measurements into colour changes. Pictures showing the design can be seen on Figure 16 and 17. Despite the strong connection to the surroundings, there are some difficulties with the structure and its positioning when compared to Christiansholm. The light sources cover a broad area, which makes it difficult to navigate without interfering with the installation. Consequently, this project works well for a temporary art installation but not for a permanent solution, which should accommodate a lot of active users.

Figure 16
L'Ö, the fictional lake
(Yann Kersalé (a), 2016)

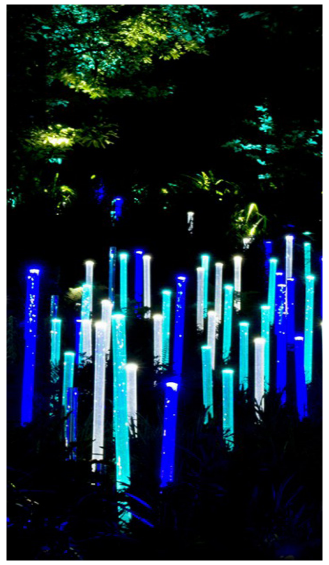


Figure 17
L'Ö's translucent rods
(Yann Kersalé (b), 2016)

4.4.3 Water Light Passage by James Carpenter

In the Museum of Jewish Heritage in New York is a permanent light installation by James Carpenter. The museum is located at the tip of Manhattan and has a view over the harbour of New York featuring the Statue of Liberty and Ellis Island (Whiting and Linder, 2012). The view that is the most crucial for the installation is the water. The installation consists of a screen of LEDs covered by diffused glass. The spacing between the LEDs is so small that perceiving their closeness to the human eye is not possible, thanks to the diffused glass. By placing mechanised video cameras on the roof of the museum, the screen can demonstrate real-time observations of the water reflections from the harbour. However, the information from the camera is first processed by special software which continually detects for the brightest area of reflected light on the water surface. The software then processes the area with the highest amount of reflected light and transfers it to the screen. It displays an abstract light frame which moves to the caustic movement of the water's surface and serves as a tool to slow down the visitors passage between two areas of the museum. Pictures of the project can be seen on Figure 18 and 19.

The installation has a strong connection to the harbour of New York and is very poetic in its abstract and discreet representation of water reflections. As the intelligent technology of the installation observes the brightest area in the harbour through a camera, it is discouraging that the visual output neglects the bright water reflection and instead demonstrates a more general water representation. There is a tremendous potential in reflection representation that goes missing. Furthermore, the use of a camera increases maintenance in case of damage or dirt on the lens from bad weather, animals, etc.

Figure 18
Water Light Passage during daytime
(Whiting and Linder, 2012)

Figure 19
Water Light Passage during nightime
(Whiting and Linder, 2012)

4.4.4 Urban Lighting in Lech am Arlberg by Dieter Bartenbach

In the mountains of Lech am Arlberg is a village which is rumoured to be the most beautiful in Europe. The village is mainly a ski resort that lives on tourism and in 2015 they made an effort to make the village even more beautiful in the dark hours. The new urban lighting design is created by lighting consultant Dieter Bartenbach in collaboration with the Mayor of Lech am Arlberg, Ludwig Muxel and lighting manufacturer Zumtobel (Urban Lighting in Lech am Arlberg, 2016). Before the changes, the old street luminaires were diffused and open, which resulted in 60 percent of light pollution. In the new design, the light sources were changed to *Zumtobel SUPERSYSTEM*, a series of luminaires with 6 to 34 independent LED tube light sources with the possibility to change direction, intensity, colour temperature and lens on each LED. An example of the product can be seen on Figure 20 while Figure 21 illustrates its use at Lech am Arlberg. The Zumtobel SUPERSYSTEM is not only used on light poles but is also attached to public buildings to complement the materials throughout the resort. The light system creates a beautiful light scene and the individually controllable LEDs create a variety of opportunities to take advantage of the different materials and their reflections. A concern is that all photographs are displayed from the snowy season, which commercially makes sense as skiing is what brings tourists to the village. However, it would be interesting to experience how the lighting design appears off-season.

Figure 20
Zumtobel SUPERSYSTEM luminaire
(Zumtobel, 2016)

Figure 21
SUPERSYSTEM in Lech am Arlberg
(Lightlife, 2016)

4.4.5 Blue Exterior Investigation Summary

To summarise upon the projects that have been analysed in the investigation section as inspiration for the blue exterior, Figure 22 has been developed where influences have been extracted and presented.

Figure 22
Blue exterior Investigations

Blue Exterior Investigations			
Project	Pros	Cons	Influences
Wintergarden, Australia	- Communicative facade - Facade structure	- Commercial - Mundane nights	- Facade & structural context - Light source positions
L'Ö, France	- Intelligent - Colour palette	- Light source structure - Impractical	- Colour matrix - Light communication
Water Light Passage, USA	- Connection to harbour - Slow down users	- Neglecting the brightness - Maintenance of camera	- Water reflections - Discrete & abstract
Lech am Arlberg, Austria	- Flexible movement - Individual light sources	- Snow showcase	- Material context - Individual control

In the first project, Wintergarden, advantages lies in its ability to have a communicative facade, which is strongly emphasised during the daytime, due to its complex structure. Its weaknesses appear at night when the artificial lights are turned on, as they undervalue the facade's potential and instead carry out a commercial and less stimulating solution. The artificial lighting takes less advantage of the impressive structure and creates a mundane environment. An element that can be used as influence for Christiansholm is the facade communication. It has the potential to be a strong element on the promenade to communicate with the surrounding neighbourhood. Furthermore, the positioning of light sources in the Wintergarden facade are discreet and hidden behind the structure which creates a homogeneous elevation, especially during daytime, because of indirect lighting solution.

Regarding the second project, L'Ö, the forte is its ability to be intelligent. The light tubes simulate a lake with the intelligent factor of colour change based on the temperature which creates a dynamic design that transforms from day to day. Another strength is that even though the colour is controlled based on temperature, the colour palette is defined by a grid of blue to green. These natural colours support the sensation of evaporation from the vegetation. A flaw is that the light source structure, as well as its placement, are impractical for Christiansholm. The inflexibility of not being able to walk in between the light tubes influences the natural walk flow in the space. For the promenade of Christiansholm, inspiration is drawn from the natural colour matrix of L'Ö, as it contributes to an attractive connection with the surroundings. Furthermore, the idea of light communication is inevitable to support the surrounding nature in the dark hours.

In the third project, Water Light Passage, the advantages lies in its ability to create a connection to the surrounding harbour and its water. The idea of slowing down visitors by giving them an abstract and thoughtful impression enhances the installation. A disadvantage is that the installation loses some of the context to the brightest lighting reflection detected by the camera, by neglecting it in the representation which in turn appears more similar to a general water movement. Furthermore, using a camera could lead to maintenance issues in case of dirt or damages onto the lens. As for inspirations drawn from Water Light Passage, the connection to the light reflections of the surrounding water, is a strong influence for the blue exterior of Christiansholm. The installation's ability to present the water movement in an abstract and discreet manner, gives the visitors the possibility to interpret and observe the installation over an extended period of time.

The last project is the Lech ski resort where the strength of the Zumtobel SUPERSYSTEM luminaire lies in its flexible movement and the ability to have each single light output specified for that assigned material or structure. The choice of applying the same luminaire throughout the city, introduces a subtle design, all the while allowing for customizability of every single light source. Regarding the weaknesses, it is problematic that the lighting is only showcased during a snow season as the snow enhances the light due to its high reflection. The inspiration for the promenade of Christiansholm comes from the luminaire's ability to be individually controlled, to emphasise the surroundings and its materials. Implementing these strengths in Christiansholm would allow to illuminate the architectural qualities of the space while simultaneously being adapted to different users.

Green Interior

4.4.6 Visby Stora Torg by ÅF Lighting

Visby Stora Torg in Sweden has been transformed from a dark and empty square to an attractive and welcoming site with a historical atmosphere from the old ruins. ÅF Lighting created this transformation by implementing a light hierarchy which highlights the existing architecture and takes advantage of its possibilities. The light hierarchy consist of multiple layers, from a practical layer for easy navigation, an intimate layer in order to make the square comfortable, an architectural layer to highlight the historical heritage of the old ruins and an atmospheric layer to highlight the trees on the square by using downlights and Gobo's with leaf projections onto the ground (Af-lighting.com, 2016). Pictures of Visby Stora Torg are shown on Figure 23 and 24.

The multiple lighting layers fit together into one holistic lighting design solution, which establishes focus on the existing architecture and the vegetation. The trees are illuminated from below, with the addition of Gobo projections from above, that project leaf patterns onto the ground surface. This effect works well, however with a critical mind in place, instead of using Gobo projections, illuminating the tree from a light source above would create shadows on the ground which vary based on the tree's seasonal changes and create diversity.

Figure 23
Center of Visby Stora Torg
(Visby Stora Torg (a), 2016)

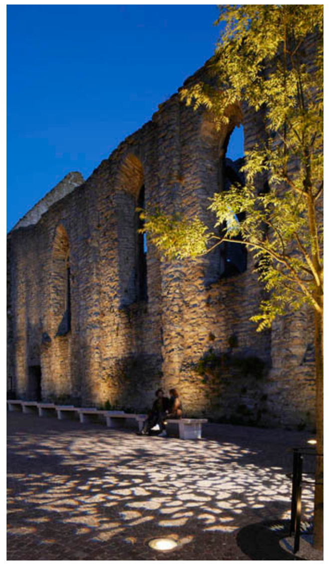


Figure 24
Visby Stora Torg Gobo projections
(Visby Stora Torg (b), 2016)

4.4.7 Twilight Epiphany by James Turrell

At Rice University in Houston is a Skyspace called Twilight Epiphany by James Turrell. The Skyspace is an open area consisting of a 196 m² large ceiling with a 16 m² square void in the centre. The roof is a composition of several specially engineered materials with a carbon-steel knife edge. A sequence of LED lights are programmed to create a light show on the ceiling in sync with sunset and sunrise. The show lasts about 40 minutes, and the light programme can operate in a variety of weather conditions (ArchDaily, 2012). Turrell's composition of light complements the natural light present at twilight, and transforms the skyspace into a locale for experiencing the beauty and reflective interactions with the surrounding campus and the natural world (Skyspace.rice.edu, 2016). Pictures of the Twilight Epiphany can be seen on Figure 25, 26 and 27.

Figure 25
Shades of Orange Skyspace
(RICE University, 2016)

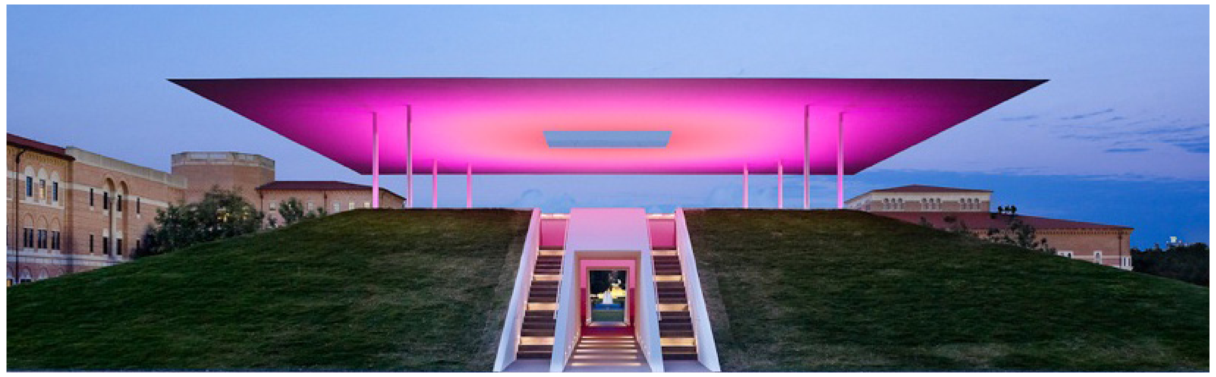


Figure 26
Shades of Pink Skyspace
(Ritani, 2016)

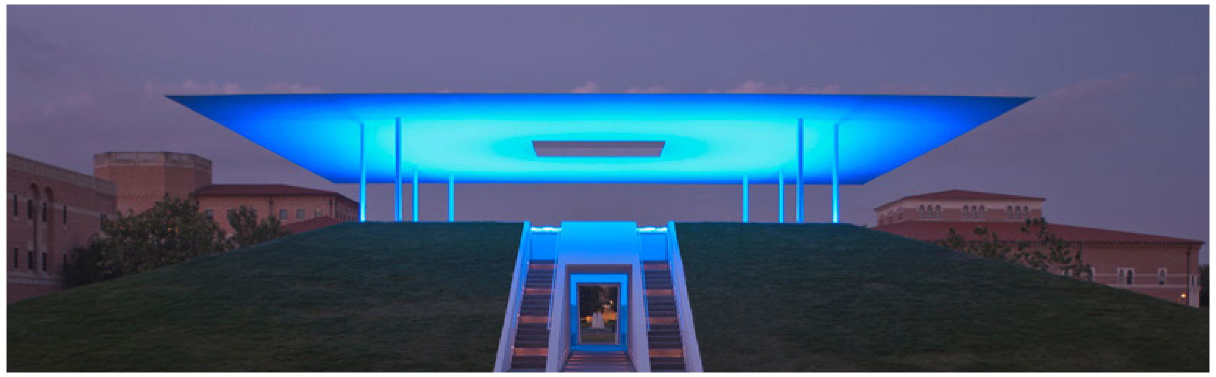


Figure 27
Shades of Blue Skyspace
(Designboom, 2016)

4.4.8 Green Interior Investigation Summary

To summarise upon the two projects that have been analysed in the investigation section as inspiration for the green interior, Figure 28 has been developed where influences have been extracted and presented.

Figure 28
Green interior investigations

Green Interior Investigations			
Project	Pros	Cons	Influences
Visby Stora Torg, Sweden	- Light layers - Historical heritage	- Static - Gobo solution	- Light hierarchy - Distinct identity - Create light zones
Twilight Epiphany, United States	- Interplay with natural light - Ceiling square contrast	- Biased colour palette - Short performance	- Nature interplay - Performance variations

The first project, Visby Stora Torg, draws strengths towards the multiple light layers that create various functionalities of illumination on the square. Concerning weaknesses, the use of static light is impending and can lead to a mundane experience over time. The Gobo solutions of projecting leaf patterns are limiting as there is an immense potential of illuminating the trees by using light sources above their position and communicating with shadows and patterns through their seasonal change. The green interior of Christiansholm takes inspiration from the light hierarchy, as it manages to gather multiple lighting solutions into a holistic approach, where each light layer has an active part in the combined lighting design. In addition to this, the ability to create a distinct identity by integrating light onto a given space is inspiring and the use of light zones makes it possible to accommodate different users and activities.

The second project regarding the green interior is Twilight Epiphany. Advantages lies in its interplay with the natural light, provided by the contrast between the LED illumination and the square void in the ceiling. The square turns the natural sky into a moving and constant changing painting. While the light colour palette is based on artistic biased choices, the authors see it as a disadvantage that the installation is pre-programmed based on fixed variables. Rather, the authors imagine having an intelligent lighting system that composes a colour palette based on the current weather conditions. Though a minor weakness, the running performance of 40 minutes is relatively short and there is potential for extending the transition phase. The elements of Twilight Epiphany that are inspirational for the green interior are the natural interplay and the performance variations. The changing seasons, the soft Nordic light, twilight and the light summer nights are part of Copenhagen's identity and should be supported in the lighting design (Natten i Byens Lys, 2007).

Chapter 5

Design

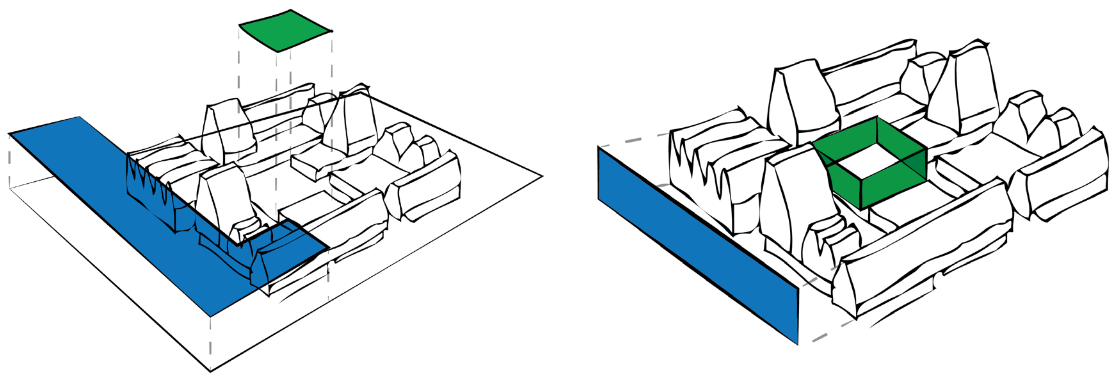
5 Design

Corresponding with the problem analysis and investigations presented, the following chapter will consist of the design for the Light Plan. The chapter begins with the section of success criteria derived from the influences of existing lighting design knowledge presented in Subsection *4.4.5 Blue Exterior Investigation Summary* and *4.4.8 Green Interior Investigation Summary*. Thereafter the next section will present the challenges that the lighting design is expected to meet rated on their level of difficulty followed by preliminary design solutions for both the blue exterior and green interior. The chapter will continue with design tests to illustrate the obtainment of necessary information for the final design, which is described in the implementation section where the chapter will conclude with the Light Plan of Christiansholm. This chapter coincides with the start of stage three, in the process model on Figure 6 explained in Section *3.2 Process Model*, where it is necessary to transform knowledge by exploring the success criteria and the challenges into preliminary design solutions, which lead to exploratory observations and tests concerning hypotheses. Ultimately it will display how the findings can help in answering the final problem statement.

5.1 Success Criteria

Through the following section, success criteria for the Light Plan of Christiansholm have been developed with inspiration from the observations of existing lighting design solutions presented in Section *4.4 Investigations*. It should be stressed that it is of interest to provide a harmonising lighting design on both horizontal and vertical surfaces as Figure 29 illustrates. The vertical surfaces will serve as a vital communicative tool and will be the main attractor for potential visitors around the harbour of Copenhagen, while the horizontal surfaces will be focused on the users to guide, entertain and inspire. The success criteria about to be presented are design criteria that must be combined and fulfilled to achieve a Light Plan that coincides with the Master Plan.

Figure 29
Horizontal and vertical surfaces
(Background ref: (COBE (f), 2016))



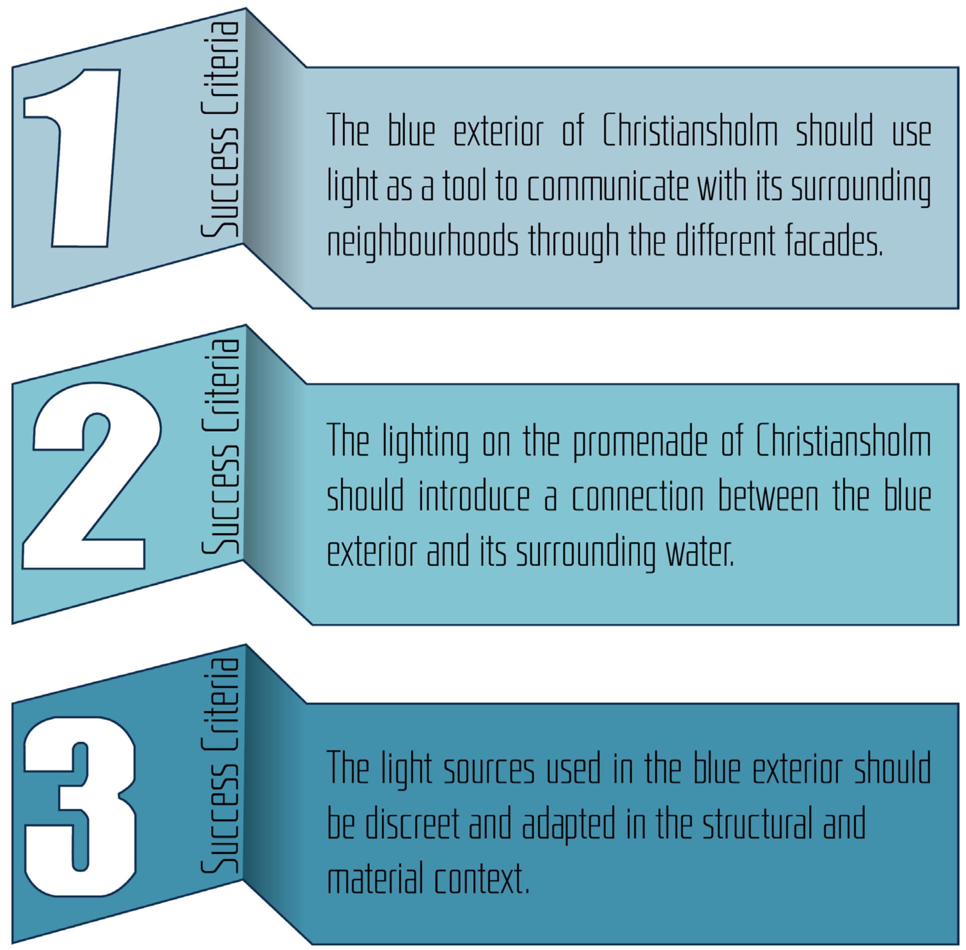
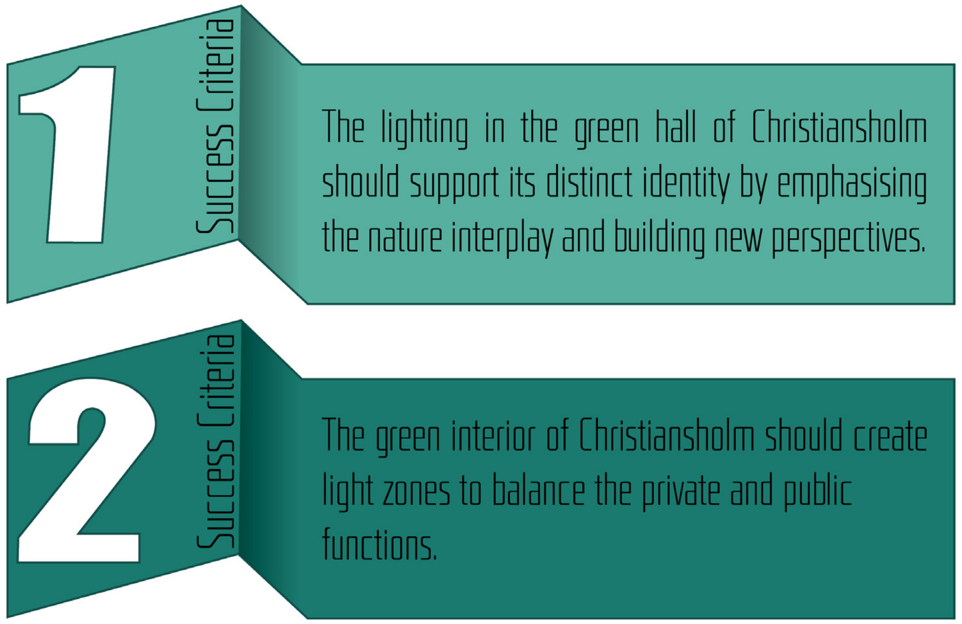


Figure 30
Success criteria of the blue exterior

In the spirit of improving the identity of the blue promenade, Figure 30 has been developed centralising the success criteria of the blue exterior. The criteria are equally important and serve as the essential measures to be met in fulfilling the holistic design. The first success criterion is inspired from the facade of Wintergarden as well as the analysis of the Master Plan regarding the blue exterior explained in Subsection *4.2.1 Blue Identity*. It deals with using the different facades of Christiansholm as a tool to communicate with the surrounding neighbourhoods in the inner harbour of Copenhagen. The second success criterion is inspired by the Water Light Passage project and the L'Ö project with their different expressions of water. It deals with water communication to introduce a connection between the blue promenade and its surrounding water. The third success criterion is inspired by Urban Lighting in Lech am Arlberg. It deals with using a flexible luminaire that can be individually controlled to illuminate different materials and surfaces on the promenade in an abstract and discreet manner. These success criteria are resolved into preliminary design solutions in the upcoming Section *5.3 Preliminary Design Solutions | Blue Exterior*.

In a similar spirit, Figure 31 has been developed, centralising the success criteria of the green interior. They are equally important and serve as essential measures to be met in fulfilling a holistic design.

Figure 31
Success criteria of the green interior



Both success criteria of the green interior are inspired by the two inspirational projects of Visby Stora Torg and Twilight Epiphany. The first success criterion deals with creating a nature interplay and build new perspectives during the dark hours to support and improve the distinct identity of the green hall. The second success criterion deals with creating light zones to balance and accommodate the private and public functions that will take place at the green hall. These success criteria are resolved into preliminary design solutions in upcoming Section *5.4 Preliminary Design Solutions | Green Interior*.

5.2 Challenges

The following section is an insight into the particular challenges that have been raised related to Christiansholm with their level of difficulty and how a lighting design can respond to them. The aim is to focus on stimulating the different users while enhancing the qualities of the promenade and the green hall.

During this investigation process, the authors visited the site to inspect the area in person and to generate photo documentation during both day- and nighttime, to understand the site-specific issues at hand. It quickly became apparent that the neighbouring islands lack light identity and endure similar lighting solutions that do not benefit the characteristics of

the space nor the users. As quoted in Light & Emotions - Exploring Light Cultures by Vincent Laganier and Jasmine van der Pol:

"Light triggers emotions in different ways and has a profound impact on the way people perceive and experience their environment" (Laganier and Pol, 2011).

The current lighting conditions in the surroundings trigger an emotion of dullness and detachment and the user does not belong to the space. Figure 32 decpits the photographer's position and Figures 33 to 38 are the selection of photographs captured on site at three different locations.

Figure 32
Map overview of photographer's position

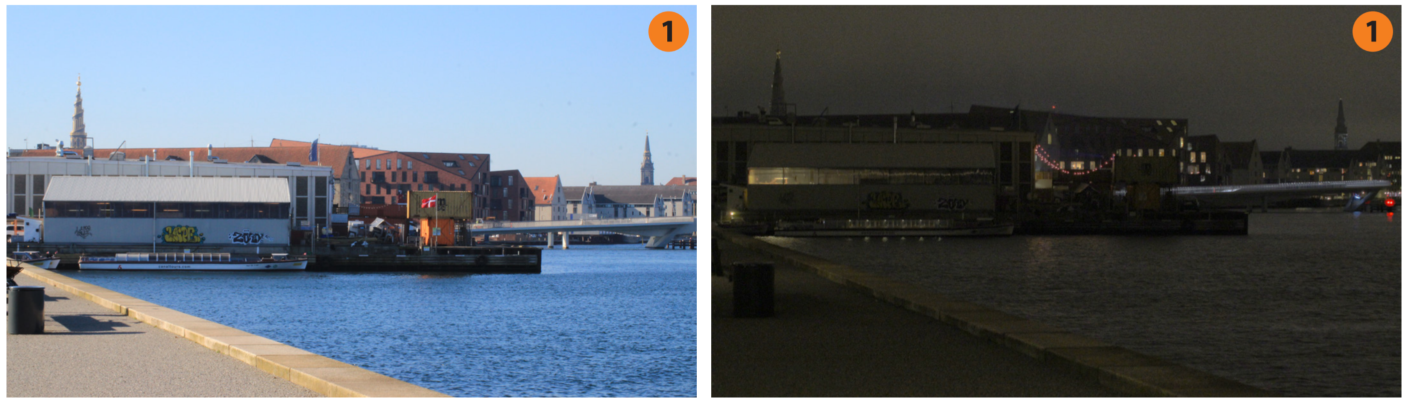


Figure 33 & 34
Point of View - Dokøen

The first view on Figure 33 and 34 are taken from the island next to Christiansholm known as Dokøen. The light grey coloured building is stationed on the north-west corner of Christiansholm where the Swimming Hall Facility will be dominating the space. The area on Dokøen does not host any function besides a clear view of the Copenhagen Opera House. At nighttime, the island is buried in silence with little understanding of the events on Christiansholm. It is very clear that there is a problem of orientation due to the low levels of illumination. This challenging point of view serves as a great space to communicate with light.

Figure 35 & 36
Point of View - Christianshavn

The second view on Figure 35 and 36 are from Christianshavn, on the promenade in front of the Danish Architecture Center. This view is essential as most commuters passing by the bridge Knippelsbro will have a direct vision to Christiansholm. The new bridge that is currently under construction, as seen in the daytime picture, does interrupt a full understanding of the promenade on the north-west side. However as it is clearly demonstrated at nighttime, the Copenhagen Opera House and the current Experimentarium logo dominate the view with their illumination. The challenge here is to attract visitors alongside the obstacles on their view while inciting the dullness of the same light solutions that are nearby.

Figure 37 & 38
Point of View - Royal Danish Playhouse

The third and last point of view on Figure 37 and 38 are taken from the promenade of the Royal Danish Playhouse, being the most vital appearance towards Christiansholm, where yearly 146.256 visitors take to the Royal Danish Playhouse (Årsrapport 2015 for Det Kongelige Teater, 2015). This number excludes a large number of visitors that simply are curious to visit the waterfront and do not partake into buying tickets for the productions. The perspective of this view is in direct contact with the promenade of Christiansholm on the north-west side. During nighttime, the Experimentarium logo illumination reflects on the water and serves as a clear communicator. The challenge with light here is to make use of the facade structure and light communication while attempting to convey a distinct local identity.

Figure 39
Challenges

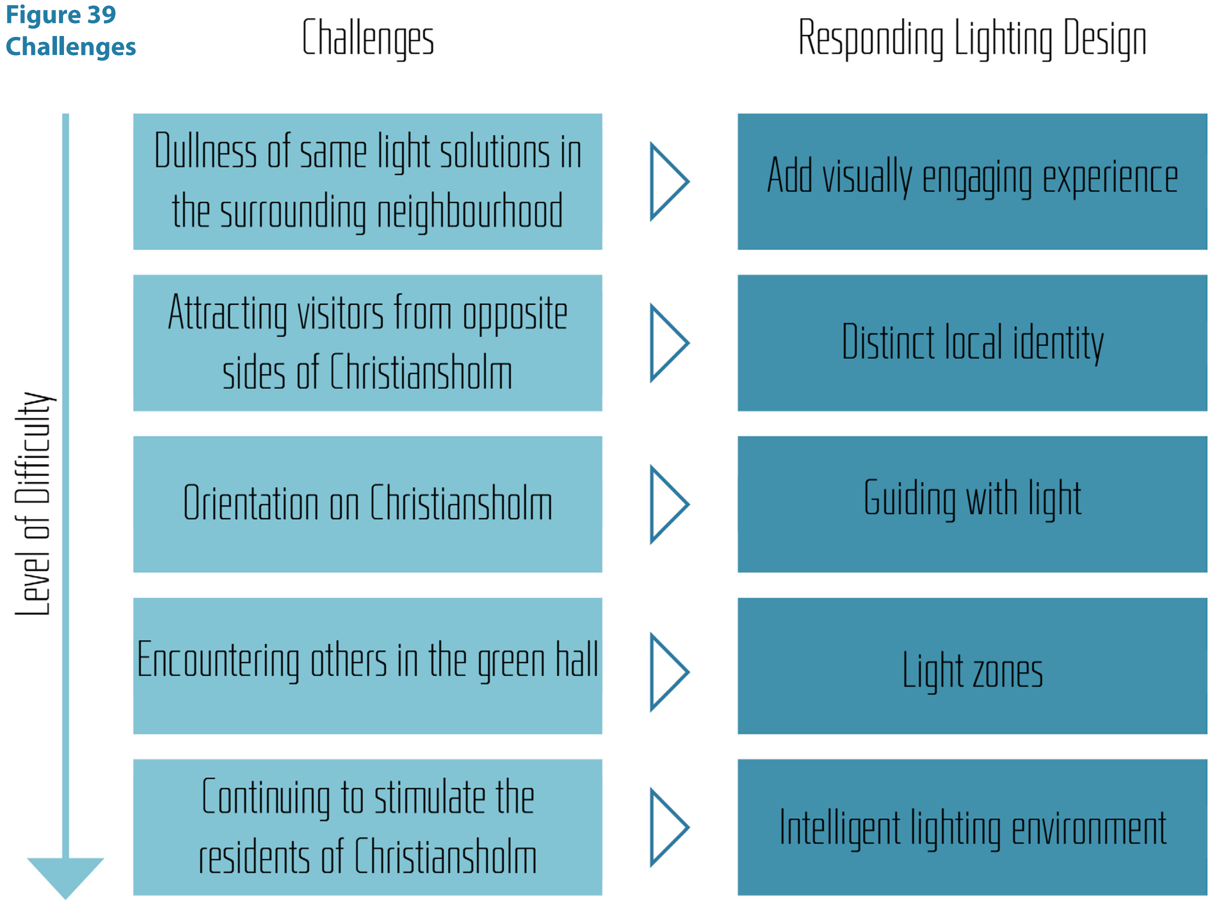


Figure 39 is developed to illustrate the challenges and how the lighting design can respond to these demands concerning their level of difficulty.

The first challenge that is evident at Christiansholm is the dullness of the same lighting solutions in the surrounding neighbourhood. The responding lighting design should add visually engaging experiences and quality to the space while orchestrating nightlife of the promenade and the green hall. Additionally, the importance of how Christiansholm will be perceived from the opposite sides of the water should be stressed. With its prime location as a pearl gem of Copenhagen, the view from the Copenhagen Opera House, Royal Danish Playhouse and Christianshavn are vital to the future characteristics of the island and how visitors will identify it. Hence, the second challenge is attracting visitors from opposite sides of Christiansholm. The responding lighting design must define a clear and distinct local identity. This identity can be established by emphasising the characteristics of the architecture by supporting the elements of the blue promenade and the green hall.

As mentioned in the introduction, the island is 29.000 m² large and will feature a maximum of 45.000 m² floor area. There will be a tremendous range of activities taking place on different sides of the promenade, the narrow paths leading to the green hall and the island itself. For this reason, facilitating orientation on the island is vital and accordingly the third challenge. This issue is expected to be solved by creating a responding lighting design that will guide the users with light and simultaneously create a light hierarchy which synthesises with the architectural materials and surfaces. The green hall aims to be the core centre of the island according to COBE's Master Plan, attracting users with outdoor activities like enjoying street food, flea markets, kids playground, etc. These are very social functions and require attention to users encountering with one another. During the daytime, the orientation of the sun will dominate where most users will be located, while during nighttime it is up to the authors to define a responding lighting design that will appeal to the challenge of encountering others. This matter can be solved by implementing light zones that speak to different users with a focus on various activities.

Lastly, as the highest level of difficulty, continuing to stimulate the residence of Christiansholm marks the fifth challenge. Many lighting design solutions that are innovative, dynamic and smart have the pitfall of being temporary installations. The authors seek out that the responding lighting design will be an intelligent physical environment that is ever changing and supports the elements of the blue and green.

5.3 Preliminary Design Solutions | Blue Exterior

In the following subsections, preliminary design solutions for the promenade are illustrated. They are used as visual guidelines to express the ideas for that particular view and should not be interpreted as final designs.

The preliminary design solutions have been developed to highlight the architectural qualities described in Section *4.1 COBE's Master Plan* while meeting the success criteria for the blue exterior established in Section *5.1 Success Criteria*, derived from the influences in Section *4.4.5 Blue Exterior Investigation Summary* and the challenges mentioned in Section *5.2 Challenges*. This coincides with stage three, in the process model on Figure 6 explained in Section *3.2 Process Model* where it is necessary to transform and evaluate knowledge. Thus, these preliminary design solutions are the means of experimenting to improve the design.

5.3.1 Architectural Outline

The first preliminary design solution proposes to highlight the distinct architectural structure frame of Christiansholm to improve the identity of the blue promenade, aiming to meet part of the final problem statement in Section *4.3 Final Problem Statement*. The elevation of the facade has a distinct composition fitted in square waveforms that determine a historical context to Christianshavn and the Royal Dockyards (Cobe.dk (c), 2016).

Figure 40
Architectural Outline
(Background ref: (COBE (a), 2016))

By highlighting the clear-cut structural beams that define the shell of the buildings with an outline of light, one takes advantage of the bold structure not only in the daytime but again during the nighttime. This preliminary design solution is illustrated from the blue exterior influence "*facade and structural context*" listed on Figure 22. It drew inspirations from the mythical island Atlantis as it marks the buildings of Christiansholm to invite users towards the palace in the centre of Atlantis being the green hall. Regarding challenges, the illuminated outline creates a foundation for a distinct local identity to attract visitors from the opposite sites of Christiansholm.

5.3.2 Streamlines

The second preliminary design solution consists of ground recessed linear light sources. The idea is to create illuminated lines within the asphalt surface on the vertical plane while maintaining a thorough connection to the horizontal planes meeting on the staircase and continuing into the water. This design takes its departure after investigating that the open promenade landscape creates a high diversity of edge conditions (Cobe.dk (d), 2016).

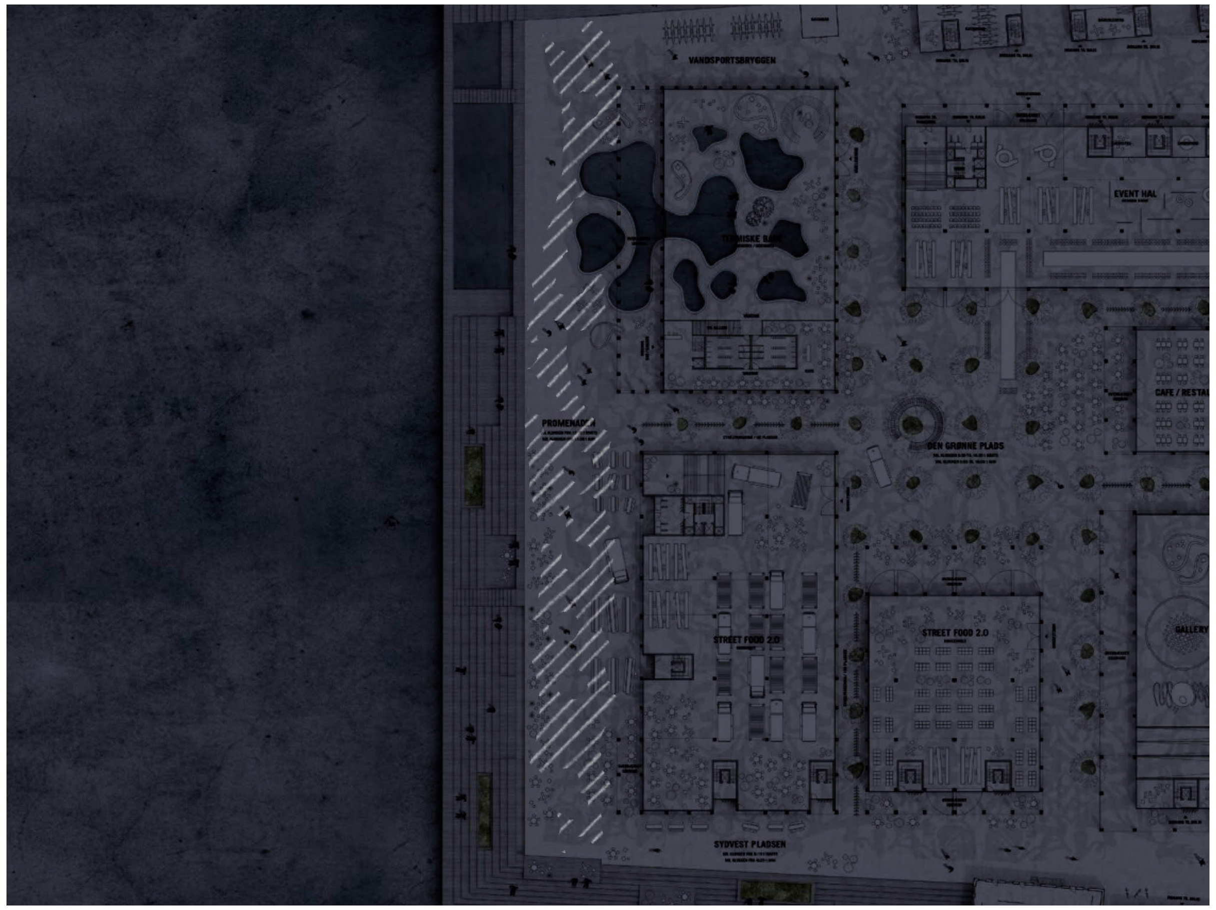
Figure 41
Streamlines
(Background ref: (COBE (a), 2016))

With this in mind, it is highly essential to use these margins in drawing associations with streams and creating a connection between the promenade and the surrounding water. The preliminary design solution is inspired from the investigation of L'Ö in Subsection *4.4.2 L'Ö by Yann Kersalé* and its ability to communicate a strong connection to water through the light. The authors acknowledged the positions of the light sources used in L'Ö and aimed to create a discreet design by using ground recessed light sources which further meet the third success criteria for the blue exterior in Section *5.1 Success Criteria*. The illuminated lines communicate the surrounding water flow, while incorporating the light sources within the landscape structure offers symmetry and integrated design. As for challenges listed in Figure 39, the preliminary design solution creates a visually engaging experience by mimicking the sensation of streams on the open space.

5.3.3 Guiding Horizontal Grid

The third preliminary design solution draws attention to the ground recessed lighting in the form of a heterogeneous grid along the north-west promenade. A distinct pattern was observed on the architectural floor plan which displays a papercut texture resembling water puddles. This brought about this design solution of guiding light along a pattern to simulate water movement.

Figure 42
Guiding Horizontal Grid
Background ref: (COBE (d), 2016)



This particular surface leads to a direct link between the open blue exterior, being the promenade, towards the more intimate yet public green interior. Therefore, the horizontal grid is designed to correspond with the success criterion of introducing a link between the blue exterior and its surrounding water as stated in Section *5.1 Success Criteria*. The recessed position of the light sources is in communication with the visitors and the residents living on top of the new industrial halls. The challenge with this preliminary design solution is guiding the users with light to explore the island's potentials and the elements of the blue exterior and the green interior as stated on Figure 10.

5.3.4 Wave Facade

The fourth and conclusive preliminary design solution for the promenade is the Wave Facade. The idea with this design solution is to incorporate light sources within the structure of the facade belonging to the Swimming Hall Facility and to achieve a uniformity of the illumination and architecture. When scrutinising the structure and the composition of the building form, the minimalistic beams provide a clean grid to create a communicative facade.

Figure 43
Wave Facade
Background: (COBE (g), 2016)

As this building is located in the prime position on Christiansholm, the authors want to communicate the waves of the surrounding water, with the help of an intelligent lighting system. The choice of communicating the waves is related indirectly to Copenhagen's harbour infrastructure and the recreational potential of water. The light is aimed to be a subtle and poetic movement that merges slowly within the architecture and illustrates the movement of the waves. This preliminary design solution seeks to meet the first two success criteria, as mentioned in Section *5.1 Success Criteria*, firstly by using light as a tool to communicate with its surrounding neighbourhoods through the facade and secondly to introduce a connection between the blue exterior and its surrounding water. It provides a strong facade communication with structural context by using the building's structural grid and form, associated with edgy wave peaks. Additionally, it possesses strong light communication with integrated light sources influenced by the investigations of the Wintergarden project, in Subsection *4.4.1 Wintergarden by Studio 505*. Concerning the challenges illustrated on Figure 39, the design solution creates an intelligent lighting environment which reacts to the natural behaviour of its surroundings and stresses a distinct local identity that is unique for the inner harbour of Copenhagen.

5.4 Preliminary Design Solutions | Green Interior

Similar to Section *5.3 Preliminary Design Solutions | Blue Exterior*, the following subsections include the preliminary design solutions for the green hall. They are used as visual guidelines to express the ideas for that particular view and should not be interpreted as final designs. The preliminary design solutions have been developed in order to highlight the architectural qualities of the green hall described in Section *4.1 COBE's Master Plan* while meeting the success criteria of the green interior established in Section *5.1 Success Criteria*, derived from the influences in Subsection *4.4.8 Green Interior Investigation Summary* and the challenges mentioned in Section *5.2. Challenges*. In comparison to the previous preliminary designs solutions of the blue promenade, it has been decided not to test the design solutions of the green hall but instead provide knowledge that can lead to further development with a project of longer duration.

5.4.1 Tree Wash | Branch Shadows

The first two preliminary design solutions aim at illuminating the characteristic tall trees found in the centre of the green hall. This lush green haven creates an intimate interior surrounded by relatively tall buildings and the idea is to illuminate this landscape during the night hours to further support and enhance the recreational identity of vegetation. The preliminary design solution on Figure 44 is Tree Wash and illuminates the trees from below. This design draws attention to the texture of the tree trunk and compliments their tall height.

Figure 44
Tree Wash
Background: (COBE (b), 2016)

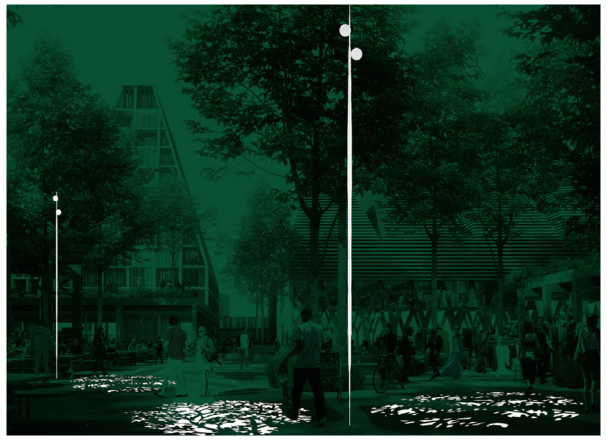


Figure 45
Branch Shadows
Background: (COBE (b), 2016)

The second design solution on Figure 45 is Branch Shadows and as its name suggests, illuminates the trees from above to simulate the distinct shadows of the tree. Both design solutions are further supported by the seasonal change, as their shape will vary throughout the year. The designs aim to meet the first green interior success criteron described in Section *5.1 Success Criteria*, which states that the lighting in the green hall should support its distinct identity by emphasising the nature interplay. This is done by focusing the light on the trees and their seasonal behaviour, inspired by the investigation of the Twilight Epiphany project as explained in Section *4.4.7 Twilight Epiphany by James Turrell*.

5.4.2 Diversion Zones | Intimate Social Areas

The next two preliminary design solutions support the landscape choices of hardscape and softscape. This interplay between the vegetation and the surfaces are fascinating and therefore the designs addresses differentiating light zones and intimate social areas. As the green hall is a private and public space shared between different users, the preliminary design solutions aim to support this identity by meeting the second green interior success criterion described in Section *5.1 Success Criteria*, stating that the green hall should create light zones to balance the private and public functions. Both designs have been inspired by the investigation of the Visby Stora Torg project explained in Section *4.4.6 Visby Stora Torg by ÅF Lighting*.

Figure 46
Diversion Zones
Background: (COBE (b), 2016)

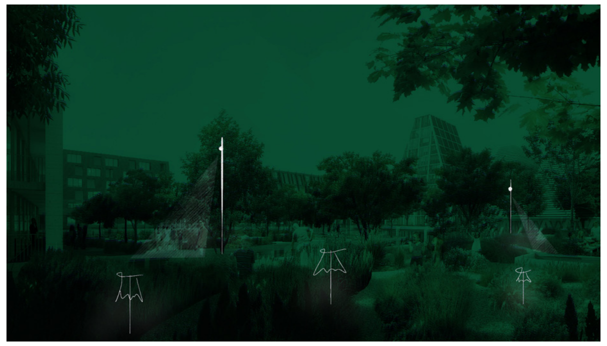


Figure 47
Intimate Social Areas
Background: (COBE (h), 2016)

The design on Figure 46 illustrates that this can be done by taking advantages of a light hierarchy which suggests using different layers of light to a variety of trees to preserve the greenery. On the other hand, the design on Figure 47, suggests using light zones to differentiate intimate areas and landscape opportunities. For instance, illuminating at different heights can improve the identity of the green hall and accommodate different users.

5.4.3 Interactive Plant Light Experience

The final preliminary design solution for the green hall is an interactive light experience supporting the distinct identity of the green interior. The authors evaluated the landscape surrounding the green hall and found a uniform grid that positions the trees in a consistent and strict distance. With this in mind, the idea is to develop an interactive light experience where the trees communicate with the users based on their use. Figure 48 and 49 illustrate the same preliminary design solution seen from a cross section and a human perspective, respectively. The essential principle of the design is that when the tree locates more users, the light will respond with brighter intensity compared to the next tree that is less populated. This design will create a natural transition in the space that will adjust the illumination based on the different users and support a dynamic experience of private and public functions, where the second green hall success criterion stated in Section *5.1 Success Criteria*, is met.

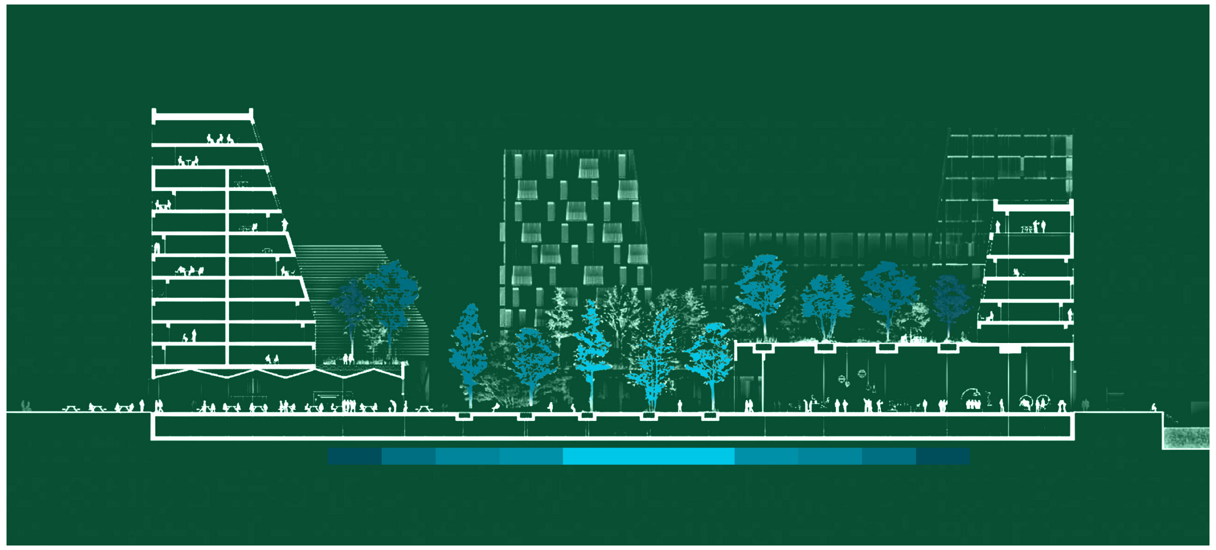


Figure 48
Cross section of green hall
Background: (COBE (i), 2016)

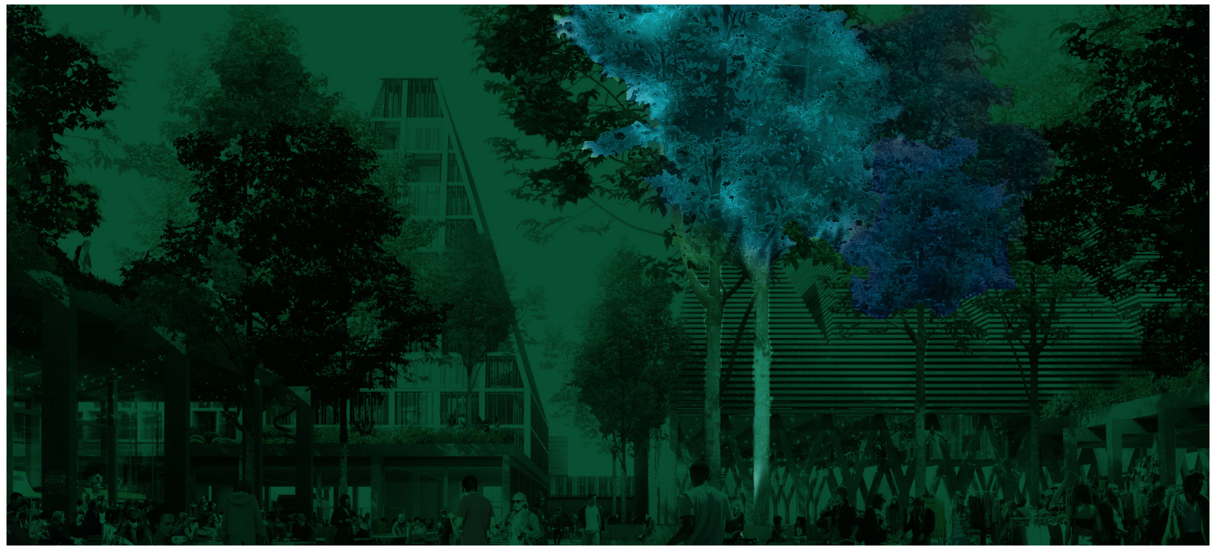


Figure 49
Interactive Plant Light Experience
Background: (COBE (b), 2016)

5.5 Design Tests

To improve design, it is necessary to test and experiment different solutions to meet the success criteria. This corresponds with stage three in the process model explained in Section *3.2 Process Model* on Figure 6, where it is necessary to transform and evaluate knowledge. The following section will elaborate the next phase in the process of design, going from the preliminary design solutions towards the final design with the guidance of testing and experimenting.

It should be noted that based on time restraints, resources have been focused on testing the blue exterior design solutions as the authors find that this space has the largest influence on the gentrification of Christiansholm. Based on the preliminary design solutions presented in Section *5.3 Preliminary Design Solutions - Blue Exterior*, investigations in both 1:1 scale and virtual explorations were conducted to meet the success criteria and improve the final design into a coherent and holistic lighting design. Throughout the subsections, the individual tests and their corresponding results will be presented.

Before elaborating on the design tests, it is important to note which preliminary design solutions from the blue exterior have been chosen to be further developed into the Light Plan. The designs coincide with the Master Plan and serve as critical parameters in improving the identity of the blue promenade while answering a part of the final problem statement.

As a primary focus, the Wave Facade in Subsection *5.3.4 Wave Facade* is an essential design solution to test, to determine if it can meet the success criteria of introducing a connection between the blue exterior and its surrounding water and if it can use lighting as a tool to communicate to its surrounding neighbourhood through its facade. Secondly, the Architectural Outline in Subsection *5.3.1 Architectural Outline* has been redesigned to fit the residential buildings only, as this elevation is a dominating facade due to its distinct composition fitted in square waveforms that determine a historical context to Christianshavn and the Royal Dockyards (Cobe.dk (c), 2016).

The preliminary design solutions of Streamlines, in Subsection *5.3.2 Streamlines* and Guiding Horizontal Grid, in Subsection *5.3.3 Guiding Horizontal Grid*, have been discouraged from being further developed as they challenged the previous two preliminary design solutions in the overall approach of creating a holistic design and instead created a disruptive illuminated environment.

5.5.1 Water Reflection | Direct versus Indirect

To strengthen the preliminary design solution of the Wave Facade described in Subsection *5.3.4 Wave Facade*, investigations took place to determine an accessible method of communicating a narrative of the surrounding water through illumination. This design solution seeks to meet the success criteria of the blue exterior stating: *"The blue exterior of Christiansholm should use light as a tool to communicate with its surrounding neighbourhoods through the different facades."* and *"The lighting on the promenade of Christiansholm should introduce a connection between the blue exterior and its surrounding water."* Before performing the test, a hypothesis was formulated:

Indirect water reflections create a clear communication of water compared to direct water reflections.

On the illustration of the preliminary design solution of the Wave Facade on Figure 43, the water effect represents clarity and portrays a distinct wave moment while the desire is to develop a discreet and abstract expression in the final design inspired by the installation, Water Light Passage as explained in Subsection *5.4.3 Water Light Passage by James Carpenter*. The design test involved exploring various techniques of representing the movement and behaviour of water. To elaborate, water is an interesting material and element to represent through lighting and an excellent opportunity to use when working with Christiansholm. Water movement is different in size and patterns, depending on multiple factors such as the wind, water flow and water area. This movement is a defining factor in understanding the reflection and thus, the design test was split into two categories: *Direct reflection* and *indirect reflection*.

The direct reflection is defined as light reflected from the water and captured directly on the camera as represented visually on Figure 50.

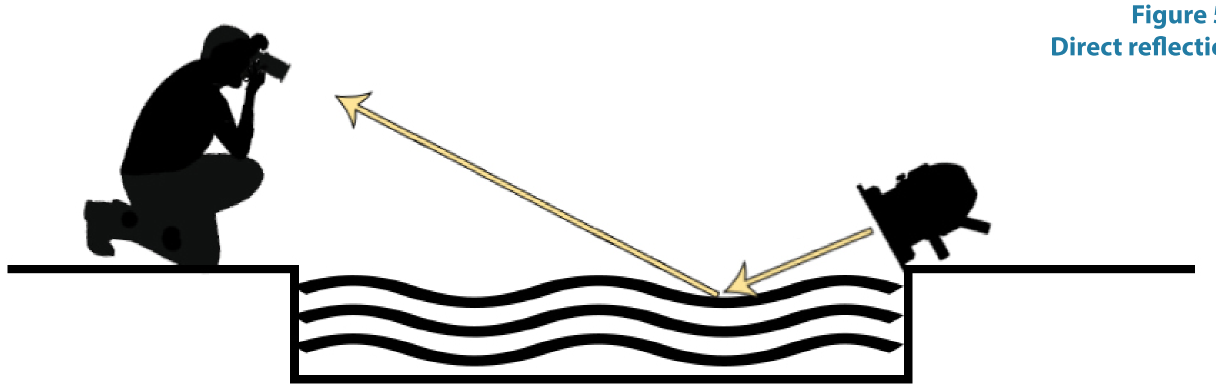
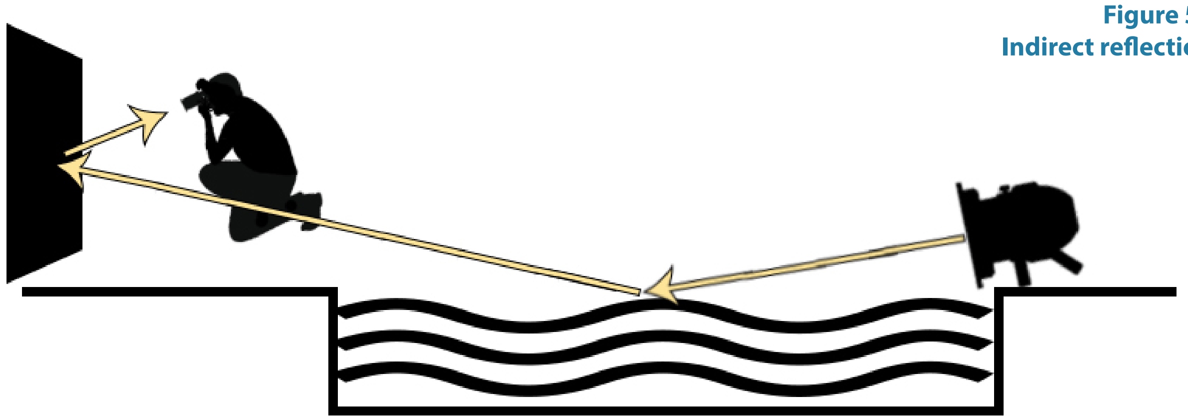


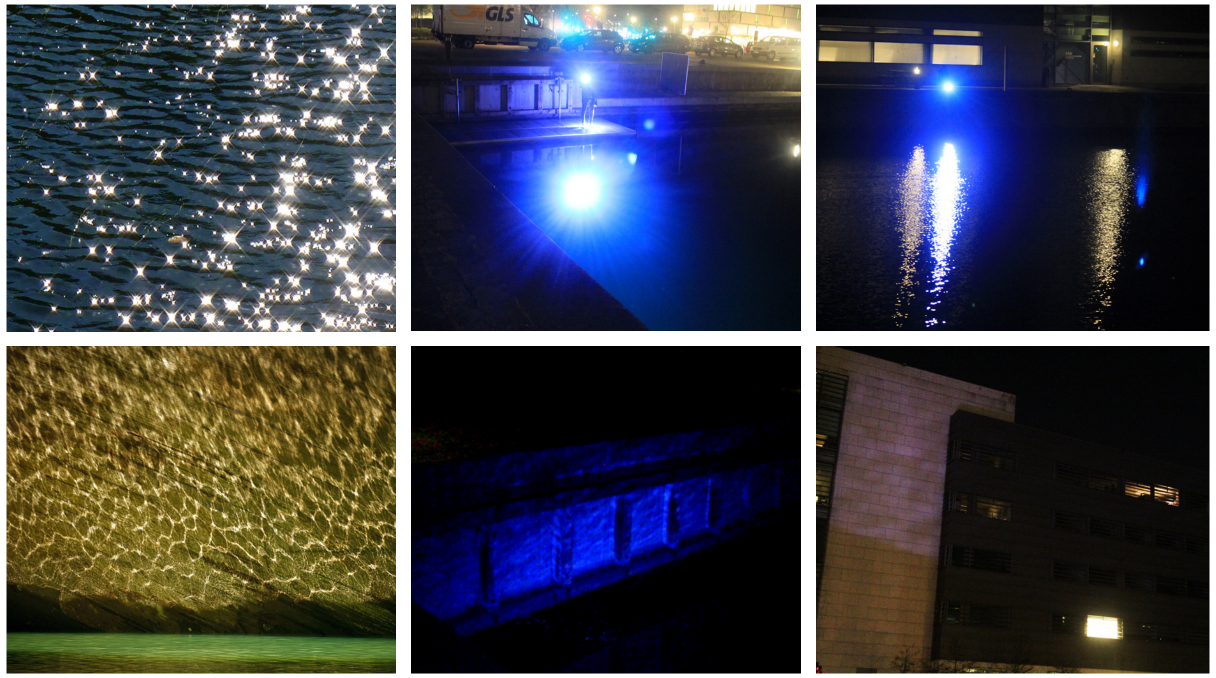
Figure 50
Direct reflection

The indirect reflection is defined as the light reflected from the water onto a surface, and then captured on a camera. A visual representation of the indirect reflection is illustrated on Figure 51.

Figure 51
Indirect reflection



Both direct reflection and indirect reflection tests were conducted on April 20th, 2016 from 22:00 to 24:00, after making sure that there was no visible sunlight for a more composed environment. The testing took place in Copenhagen, on the promenade between A. C. Meyers Vænge 15 and Frederikskaj 12. This environment was chosen due to its resemblance to the promenade of Christiansholm with close contact to the water. The light fixtures used were ADJ Ultra GO PAR7X, a battery powered PAR Lamp, which allowed for easy manoeuvring. A compilation of photographs taken during the test is illustrated on Figure 52, where the top three pictures display the direct reflection and the bottom three view the indirect reflection.



(Shropshall, C., 2016)

(National Geographic, 2016)

Figure 52
Test compilation of direct versus indirect reflections

Due to difficulties of capturing the actual effect on a DSLR camera as a result of the low light intensities, reference pictures are included on the left of each row as an impression of the effect set out to achieve with these tests. As the figure demonstrates, the experiments provided two different representations of water. When the water is in movement, the direct reflections created a gleaming effect. The light reflected at the wavetops drew associations to blinking stars in the universe while it simultaneously retains the water's movement, as the glistening reflections travel with the waves. This effect can be elegant and discreet when tested with a small light source while a large light source increases the risk of having a wide uniformal spot in the water, resulting in disruption of the gleaming effect.

The indirect reflection test results revealed a similar representation of water reflections that one anticipates. The test demonstrated a moving pattern of circular shapes that were ever changing in the moving water. The texture generated a visual resemblance to that of fish scales or foam, while the effect evoked a clear reference to water and its movement. The result of the test confirmed the hypothesis. It demonstrated that water is communicated clearer through indirect water reflections compared to direct water reflections. However, as the aim is to achieve an abstract and discreet design, the indirect water reflections are impractical as this is the most prominent representation people know. Based on these findings, it was decided to use the appearance of direct reflection on the facade of Christiansholm.

5.5.2 Blurred versus Linear

As a result of the findings in Subsection *5.5.1 Water Reflection | Direct versus Indirect* stating that the appearance of the Swimming Hall Facility will illuminate the effect of direct reflection, investigations were made to further develop the facade lighting. The investigation takes its departures in analysing water as a communicator through light and how this can be represented in an abstract and discreet manner. The reason to test this design solution is to meet the second success criterion of the blue exterior on Figure 30, stating: *"The lighting on the promenade of Christiansholm should introduce a connection between the blue exterior and its surrounding water"*. Furthermore, during reflection observations, two different appearances were recorded as Figure 53 illustrates and this raised a question of understanding water reflections. Therefore, a hypothesis has been formulated to be confirmed or rejected for these observatory explorations:

Water reflections as a texture is better understood as moving water from up close than from afar.

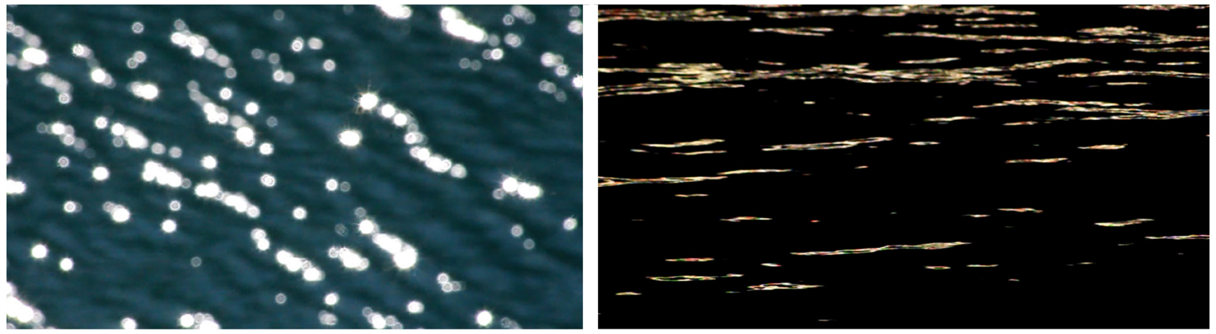


Figure 53
Blurred versus linear textures

When looking at the still images from the video footage as Figure 53 illustrates, there are many reasons as to why the two textures are so different from each other. The picture on the left is taken at midday from the fourth floor of Aalborg University Copenhagen, where the sun plays a central role on the reflection in the water. The picture on the right is taken at nighttime from the promenade of the Royal Danish Playhouse, where the reflection are directed from the Experimentarium building on the Paper Island. The height difference is certainly a key element in characterising the texture of the reflections while an essential factor to highlight their differences is that the picture on the left is determined by the sun as the primary light source while the logo of Experimentarium illuminates the picture on the right.

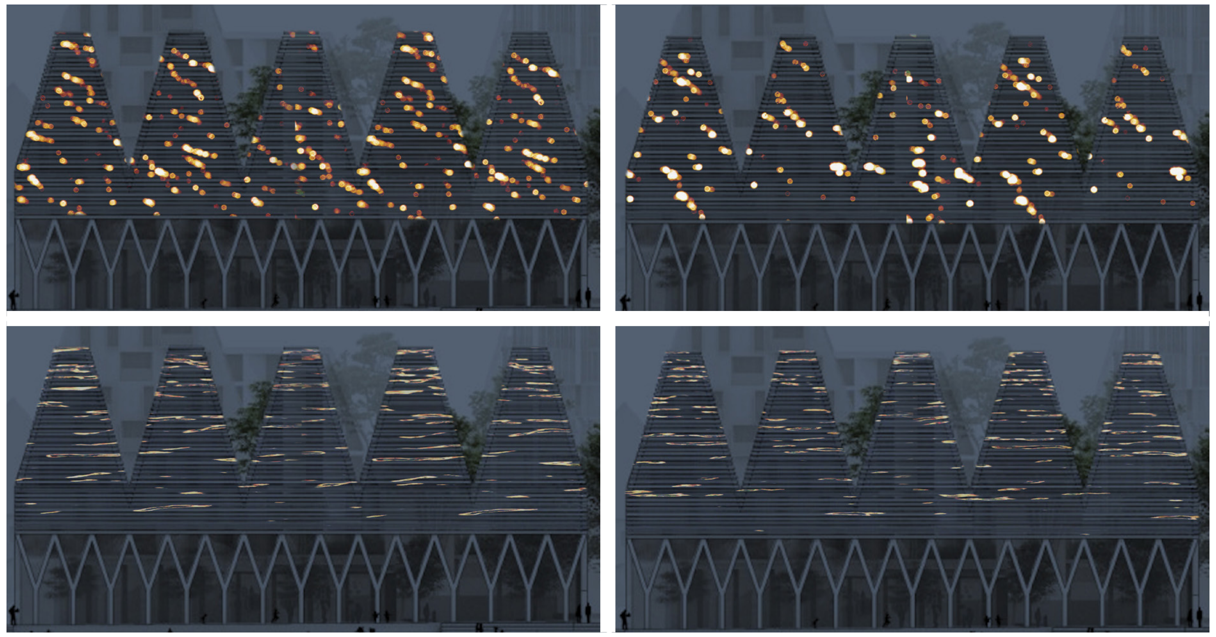


Figure 54
Texture experimental observations
Background: (COBE (I), 2016)

Using these textures as communicators of light, it was determined to apply them upon the facade of the Swimming Hall Facility to decide which design is better understood. Figure 54 is a compilation of the experimental observations that took place to verify the different integrated lighting concepts. These illustrations may be perceived as light projections and therefore, it should be pointed out that they are a conceptual representation of the lighting design that the authors seek to produce and do not represent the final design.

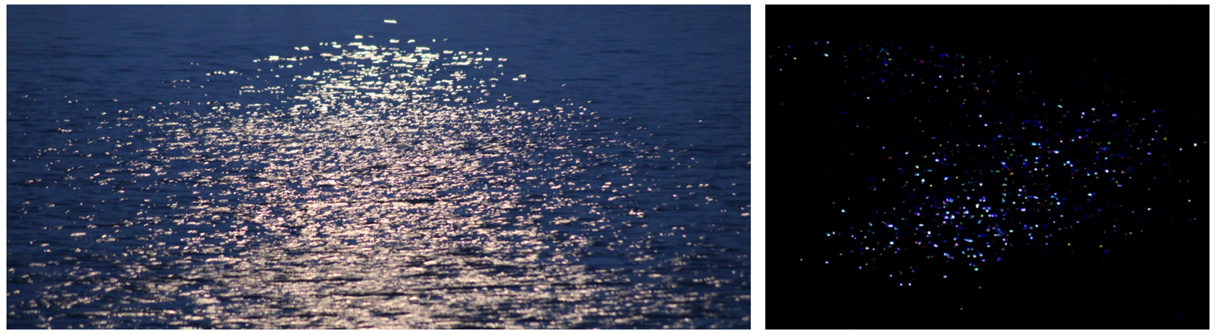
In closure, the results of the experimental observations confirmed the hypothesis that water reflections as a texture are better understood as moving water from up close than from afar.

However the linear surface is hard to achieve when scrutinising the facade construction and the blurred texture further exceeds the possibilities of integrating a lighting system within the facade, which will be further discussed in Section *5.6.1 Swimming Hall Facility Facade*.

5.5.3 Colours of Reflection and Movement

It should be noted that on the night of direct and indirect reflection testing, a fortunate coincidence took place that initiated a follow-up experiment concentrating on further improving the lighting design for the Swimming Hall Facility facade. Upon the dark sky of April 20th, 2016 was a full moon, which illuminated the wave peaks and created beautiful reflections as displayed on Figure 55.

Figure 55
Full moon reflections

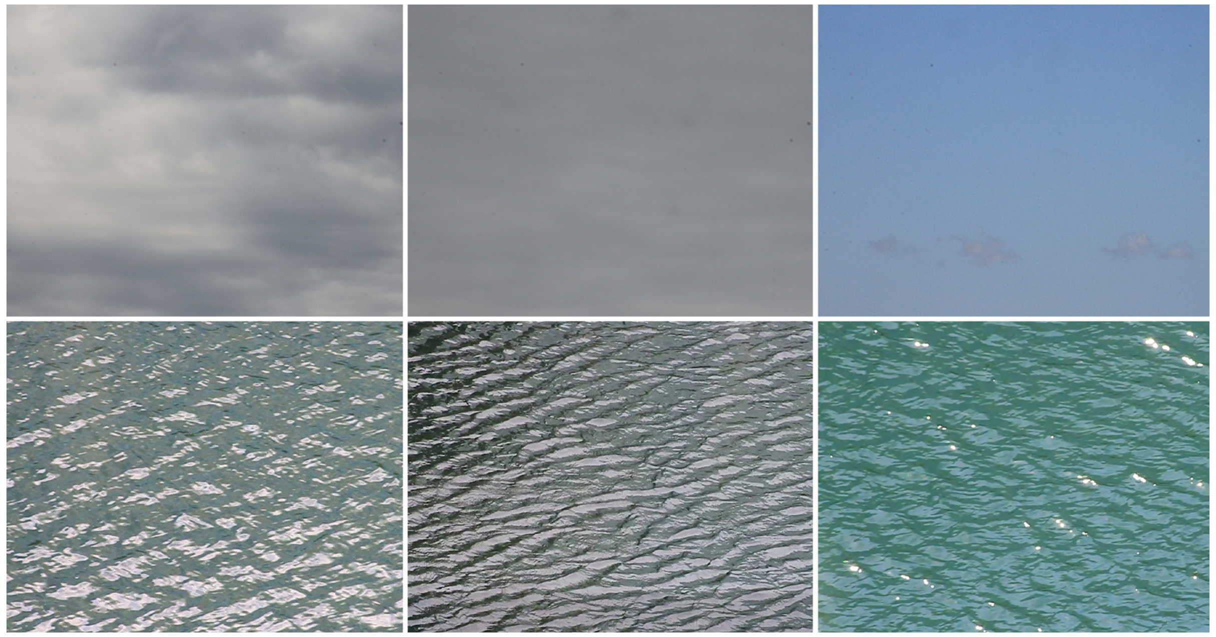


It became apparent that the illumination from the moon being reflected onto water was a cool white temperature with tendencies of blue compositions. It was a superior version of the effect attempted in the direct reflection experiment and this is the reason the authors chose to explore further the possibilities of improving and supporting the identity of the blue promenade in order meet the success criteria of the blue exterior, as Figure 30 illustrates. The aim was to build a colour scheme library from observing different weather conditions and how this affected the colour of water and light reflected within it. The hypothesis for this experiment follows:

Observing different weather conditions can determine a site-specific colour scheme which supports the characteristics of the space while complying with the surrounding lighting environment.

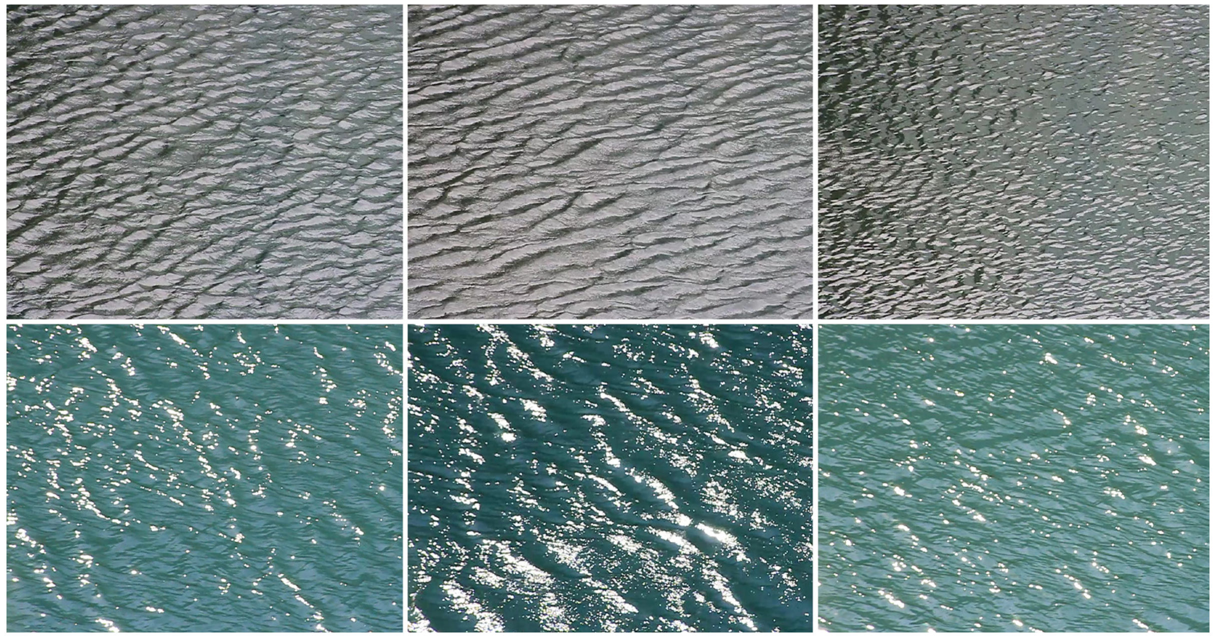
The results would be used to guide the users through the light journey of the day. An assembly of photographs taken during observations is illustrated on Figure 56. The investigations took place on the 13th April, 2016 at 12:00, the 18th April, 2016 at 12:00 and the 20th April, 2016 at 13:00. The top row pictures illustrate the sky while the bottom row pictures illustrate the water.

Figure 56
Different weather condition observations



The reason for observing the colour of reflection in the water in regard to the design is to draw attention to its ever-changing appearance and how vital it is for the promenade of Christiansholm. However, this understanding alone is not enough to define the parameters of the lighting design to be integrated into the north-west facade. Water fluctuates regularly and the movement is critical to apprehend the abstract and discreet design.

Figure 57
Different water movement observations



Therefore, video observations took place to define a wave guideline which specifies parameters to be used in the intelligent lighting design. An assortment of still images from the video footage is composed on Figure 57. The video observations are approximately 10 to 15 minutes long and alone in that time span; it is evident that movement of the water has a defined texture with a straightforward understanding of direction. Having collected this vast observatory information, it was essential to test the gathered material upon the relevant space and how this is improving the identity of the blue promenade.

When applying the colours of reflection from the observations onto the facade, it quickly became apparent that the cool white temperature with tendencies of a blue composition is not understood as an integrated part of the architecture and does not comply within the urban fabric of the harbour, as Figure 58 and 59 illustrates.

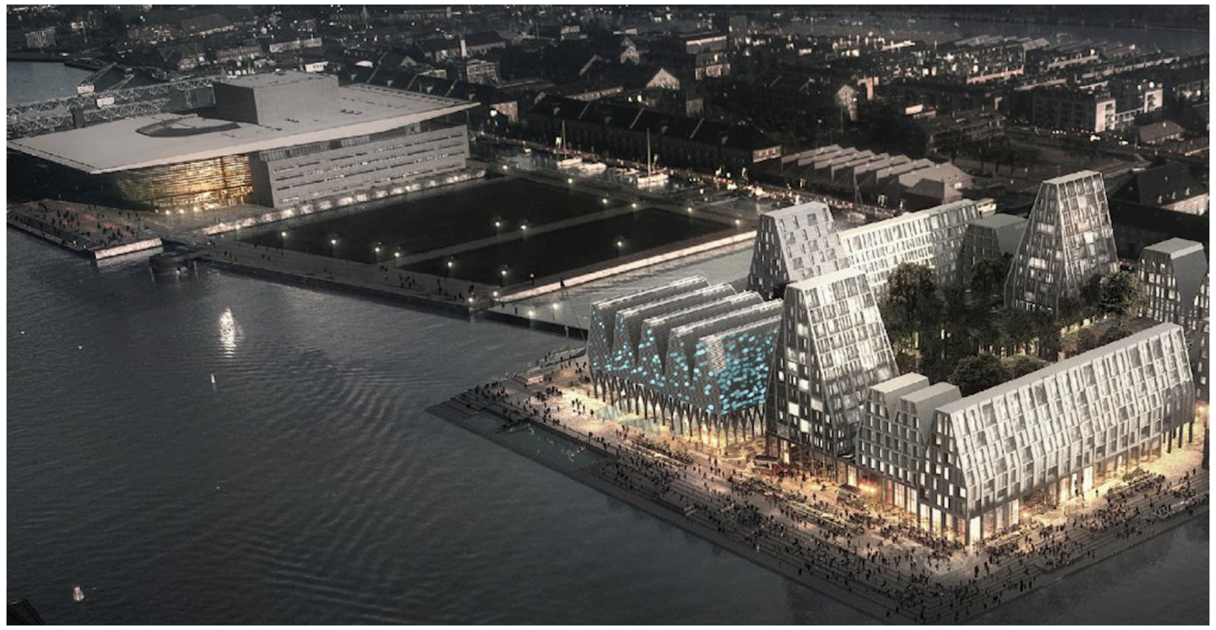


Figure 58
Light shades of blue
Background: (COBE (j), 2016)

Figure 59
Dark shades of blue
Background: (COBE (j), 2016)

These colours of reflection insinuate relations to the blue element but eliminate the design strategy of creating an abstract and discreet solution that complies with the surrounding lighting environment. Additionally, applying a water movement direction that moves in the opposite direction from the real-time environment only disturbs the uniformity and composition of intelligent lighting system. Therefore, it was necessary to take the surrounding night environment into account and find a warmer colour temperature and apply a system that accommodates to the water movement in defining the speed and extent of the gleaming effect. In closure, the results of the observations reject the hypothesis as the colour scheme is complying with the lighting from the surrounding neighbourhood but disrupts the environment. An illustration of the refined design with tones of warm white is illustrated on Figure 60.

Figure 60
Refined design with tones of warm white
Background: (COBE (j), 2016)

5.6 Implementation

This section will elaborate on the implementation required to establish a foundation for a lighting concept in the Light Plan. It will emphasise the recommended implementation solutions of technical parameters and it should, therefore, be viewed as guidelines rather than final products. This section coincides with stage three, in the process model on Figure 6 explained in Section *3.2 Process Model*, where it is necessary to transform and evaluate knowledge.

5.6.1 Swimming Hall Facility Facade

The knowledge from the exploratory observations in the design tests of Section *5.5 Design Tests* concluded on a final design of the Swimming Hall Facility which uses the appearance of direct reflection with a blurred texture and colours of reflections that comply with the surrounding lighting environment in a abstract and discreet solution. The following subsection scrutinises light source positions as well as the technical implementation of an intelligent lighting system. The goal is to provide a holistic design implementation that improves the identity of the blue exterior.

Light Integration

As briefly mentioned in the closure of Section *5.5.3 Blurred versus Linear*, the two different textures of light reflections require different light sources and positioning, as illustrated on Figure 61. By taking a starting point at the blurred texture design solution, it would be possible to integrate the light sources along the inside of the building's facade, in the void areas between the beams. The second texture design solution being linear, would require light sources onto the facade to make fluid movements vertically. However, since that will create a structural disturbance, this solution is ruled out. Another way of creating this effect is to map a projection onto the facade from a lamppost. This solution is relatively discreet but disrupts the otherwise open promenade. Based on this investigation it was decided to pursue the Blurred design for the facade of Christiansholm. The winning solution positioned on the left side of the figure is aesthetically pleasing during the daytime as the light sources are hidden and not interfering with the architecture.

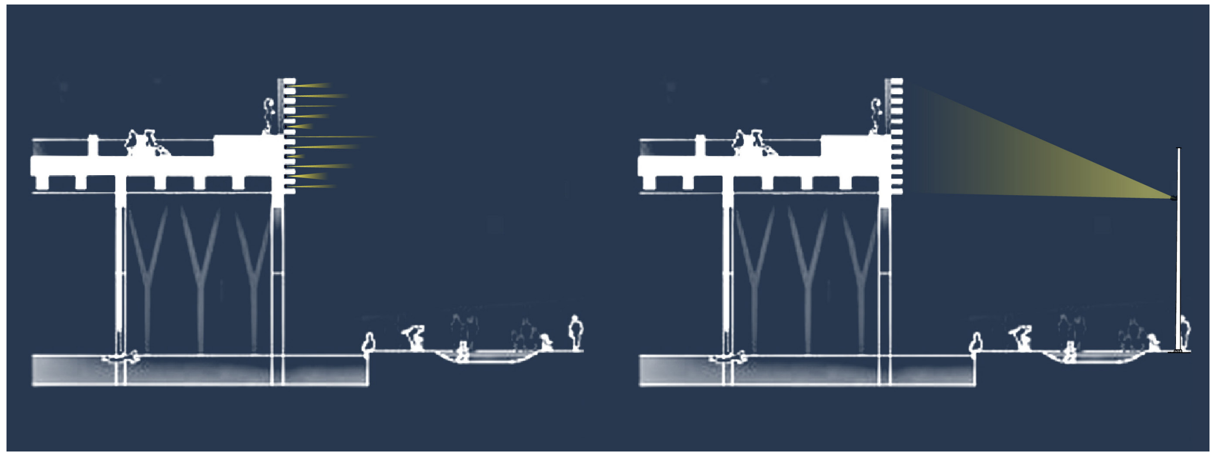


Figure 61
Light integration of Swimming Hall Facility
Background: (COBE (k), 2016)

Intelligent Lighting System

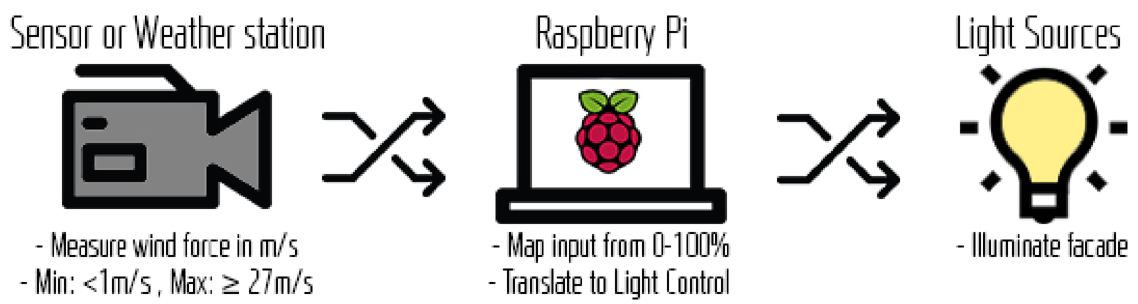
As described in Section *1.3 Intelligent versus Interactive Lighting Design*, an intelligent system is a machine with an embedded computer that can gather and analyse data and communicate with other systems (WhatIs.com, 2016). As the first step in the process, one must derive what data is going to be used, to determine the necessary hardware and associated software. It was derived in Subsection *5.5.3 Colours of Reflection and Movement* that the speed and extent of the gleaming effect should be dependent on the real-time water movement to create a connection to the surroundings. This means that the light points, as well as their fade speed, are controlled as a result of the real-time weather conditions. The authors see three possible hardware solutions each with their advantages and disadvantages.

The first solution is to use a camera to observe the movement of the water. This solution was quickly discarded due to concerns regarding maintenance, as well as fears that the waters many uses might interfere with the system, if obstacles like people or animals enter the camera's view. The second solution is to implement sensors at Christiansholm to measure the water's movement. The sensors that come to mind are wind force and water flow sensors. A strength of using sensors is that the actions are captured on the exact location making it highly site-specific. However, it has the disadvantage of additional maintenance in case of damage or malfunctions of the sensors. The third solution is to gather weather information Online from the nearest weather station of a database such as the Danish Meteorological Institute (DMI). The advantages of this solution are little maintenance and no expenses for sensors. The disadvantage is that DMI's closest weather station is situated 5 kilometres away from Christiansholm, which could result in minor weather differences.

Both the second and third solution are based on the small single-board computer Raspberry Pi. The Raspberry Pi is an obvious choice as the embedded computer of the intelligent system because of its small size comparable to a credit card and low price of around 400 Danish Kroner. Associated with the hardware presented above, software is developed to measure an input from either of the two hardware solutions, converting the input from weather data to light controls and bypassing the information to the light sources. Targeting the uncertainties of whether the lights should be controlled based on wind force or water flow is not crucial for now. Wind force is measured in metres per second (m/s) while water flow is measured in knot, which is the standard maritime speed measure. However, the translation from knot to m/s is done by multiplying the amount of knots by 0,514. For simplicity, the following description will be based on wind force only, even though it could easily be converted to water flow. Wind force is categorised on the *Beaufort scale*, which will also be used as a guideline for the control of the facade lighting (Met Office, 2016). The speed and extent of the gleaming effect are determined by the lower limit being less than 1 m/s described as *calm* and the upper limit being *storm* of 27 m/s, as these boundaries cover the most common weather conditions in Denmark. Any wind force measured above 27 m/s will be interpreted as storm and not create an additional effect on the facade. When a sensor either measures wind force or gathered data from a weather station, it is mapped linearly between the lower and upper

limit. For instance, some examples can be wind forces measured of 0,5 m/s, 13,5 m/s and 27 m/s and received as input on the Raspberry Pi. The Raspberry Pi then processes these measures to map the values linearly between the upper and lower limits, resulting in 0%, 50% and 100%, respectively. These percentages are equivalent to the pace of the dimming, as well as the number of gleaming spots and they determine which light sources that are turned ON or OFF with their respective fade-time. The different stages of the process are illustrated on Figure 62.

Figure 62
Intelligent Lighting System
Raspberry Pi Logo: (Raspberry Pi, 2016)



The final result aims to simulate the existing environment as the amount of movement in the water is based on the effect of the present wind force and water flow, which is also the parameters that affect the light system on the facade.

5.6.2 Residential Facade

As briefly mentioned in Section *5.3.1. Architectural Outline* and illustrated on Figure 40, the elevation of the north-west facade excluding the Swimming Hall Facility has a distinct composition. Fitted in square forms, the residential facades creates a unique spatial structure of pushing and pulling exterior which is adapted into sharp waveforms that determine a similar historical exterior context to Christianshavn and the Royal Dockyards (Cobe.dk (c), 2016). The preliminary design solution suggested highlighting the structural beams that define the shell of the buildings. However, the authors find that the outline of the grid created within the facade is a vital and available canvas to enhance and improve with light and further support the distinct identity. To design along the first and second success criteria listed on Figure 30, it was decided to highlight the horizontal beams along the residential facade.

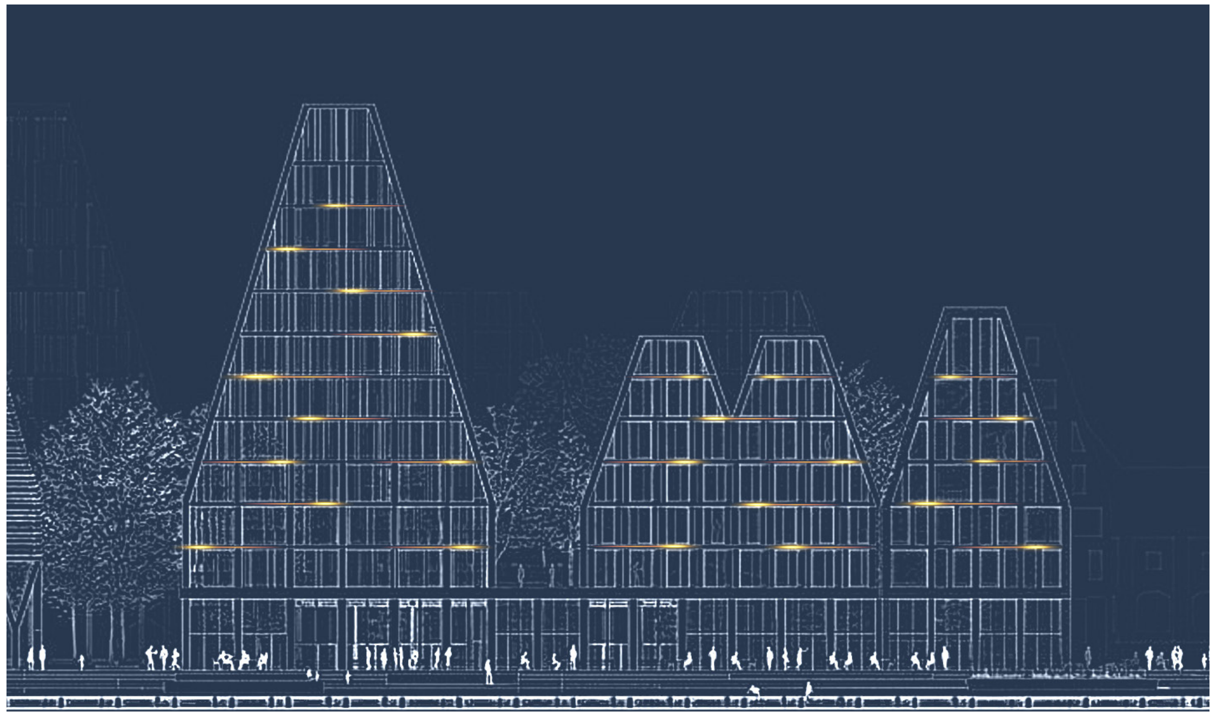


Figure 63
Residential facade elevation
Background: (COBE (I), 2016)

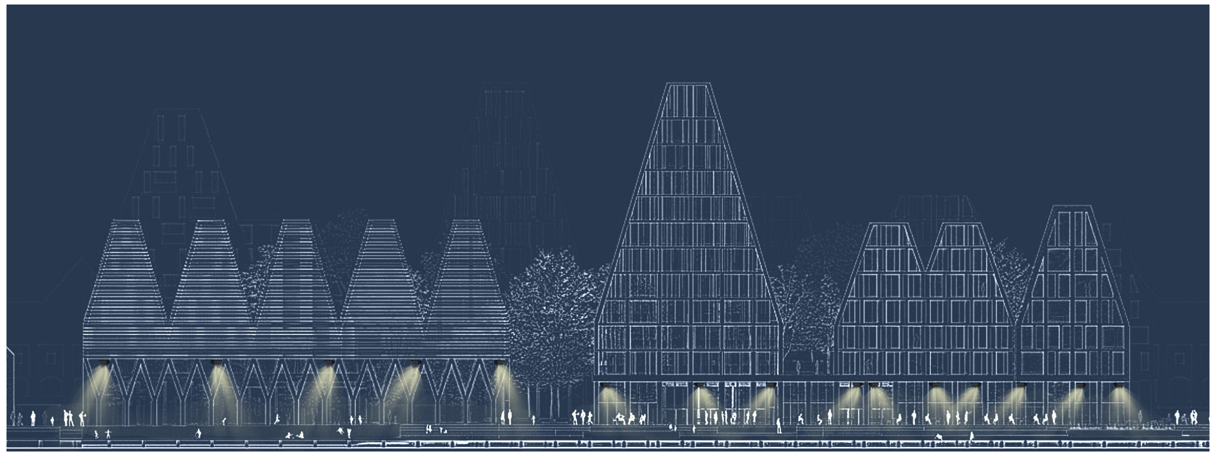
The decision to work with the horizontal beams is due to a number of reasons. Essentially, as the Swimming Hall Facility is communicating light along its horizontal lane, it would be disturbing to all of a sudden illuminate along a vertical lane. The choice would interrupt the spatial composition and understanding of the natural horizontal water movement. As a result, the horizontal lit beams simulate the existing environment, as the amount of movement in the water controls the movement of the light in the beams which is also the parameters that affects the light system on the Swimming Hall Facility facade. The visual output of the two facades are different from one another. However, the message being communicated is the same. This solution can be implemented in an abstract and discreet manner that improves the identity of the blue exterior, as illustrated in Figure 63.

5.6.3 Ambient Lighting Layer

The design tests have been focused on communicative facade lighting, however, it is necessary to look at the practical lighting for the general manoeuvring on the blue promenade. As mentioned in Section *5.5 Design Test*, the preliminary design solutions of Streamlines and Guiding Horizontal Grid has been discouraged from being further developed as they conflict with the facade lighting. Simultaneously, in Subsection *5.2 Challenges*, it was mentioned how the general lighting of the neighbouring surroundings are very similar and lack identity. To break this tendency, the practical lighting of Christiansholm takes inspiration from the ski resort Lech am Arlberg investigated in Subsection *4.4.4 Urban Lighting in Lech am Arlberg by Dieter Bartenbach*. The main influences from the lighting design in Lech am Arlberg lies in the ability to control and specify every single light point regarding directions, colour, intensity,

lens, etc. However, in contrast to the SUPERSYSTEM from Zumtobel, it is the ambition to have a more discreet luminaire integrated into the architecture of the promenade. The promenade is surrounding the public halls all around the island and it is the goal to incorporate the practical light sources on top of the industrial halls as an integrated element of the facade. An illustration of the light source positions is displayed on Figure 64.

Figure 64
North-west promenade
Background: (COBE (I), 2016)



Every single light point is going to be specialised for its relative purpose both in regard to functional and material context. The parameter of material context is of great importance, as it supports and enhances the architecture by specifying light sources that respect the public realm and create an identity. This material context allows for a diverse light environment and it is anticipated that the possibility of creating light zones for different uses, results in a stimulating and pleasant environment, as a contrast to the conventional monotone lighting solutions currently found around Christiansholm.

5.6.4 Green Interior

As argued in Section *5.5 Design Tests*, resources were focused onto the blue exterior because of time restraints. Therefore, the implementation of the green hall is based on the preliminary design solutions from Section *5.4 Preliminary Design Solutions | Green Interior*. With that in mind, the green hall is still an important space with a variety of possibilities for site-specific lighting design. The preliminary design solutions of the green hall are chosen on behalf of their aim to meet the success criteria previously illustrated on Figure 31.

Beginning with the two preliminary design solutions dealing with illumination of trees being Tree Wash and Branch Shadows in Subsection *5.4.1 Tree Wash & Branch Shadows*, the first green interior success criterion described in Section *5.1. Success Criteria* is met. The success criterion stated that the lighting in the green hall should support its distinct identity by emphasising the nature interplay. The idea is to use a mixture of the two techniques to create different areas and expressions around the green hall. The trees will create a natural interplay and different light zones. Furthermore, the tree wash is expected to have coloured light which is inspired by the Twilight Epiphany project described in Subsection *4.4.7 Twilight Epiphany by James Turrell*. The desired concept creates an interaction with the real-time weather conditions and changes the colours to create an interplay with both analogous and complementary colour sequences to accommodate performance variations. As for general lighting, the same system from the blue exterior is continued inside the green interior. With the many different materials from the hardscape and softscape, it is an ideal opportunity to emphasise these surfaces by specialising individually controlled lights for each material. Furthermore, the full controllability expands the possibilities to create different light zones by varying the amount of illumination in various areas, establishing both intimate and social spaces, which meets the second green interior success criterion stating that the light zones should balance the private and public functions. By merging these different designs together into a holistic solution as displayed on Figure 65, the lighting improves the identity of the green interior and provides a unique space that stands out in the neighbourhood. The diverse lighting design ensures that the green interior does not only appear welcoming during the daytime but also during the nighttime, where it will build new perspectives and experiences.

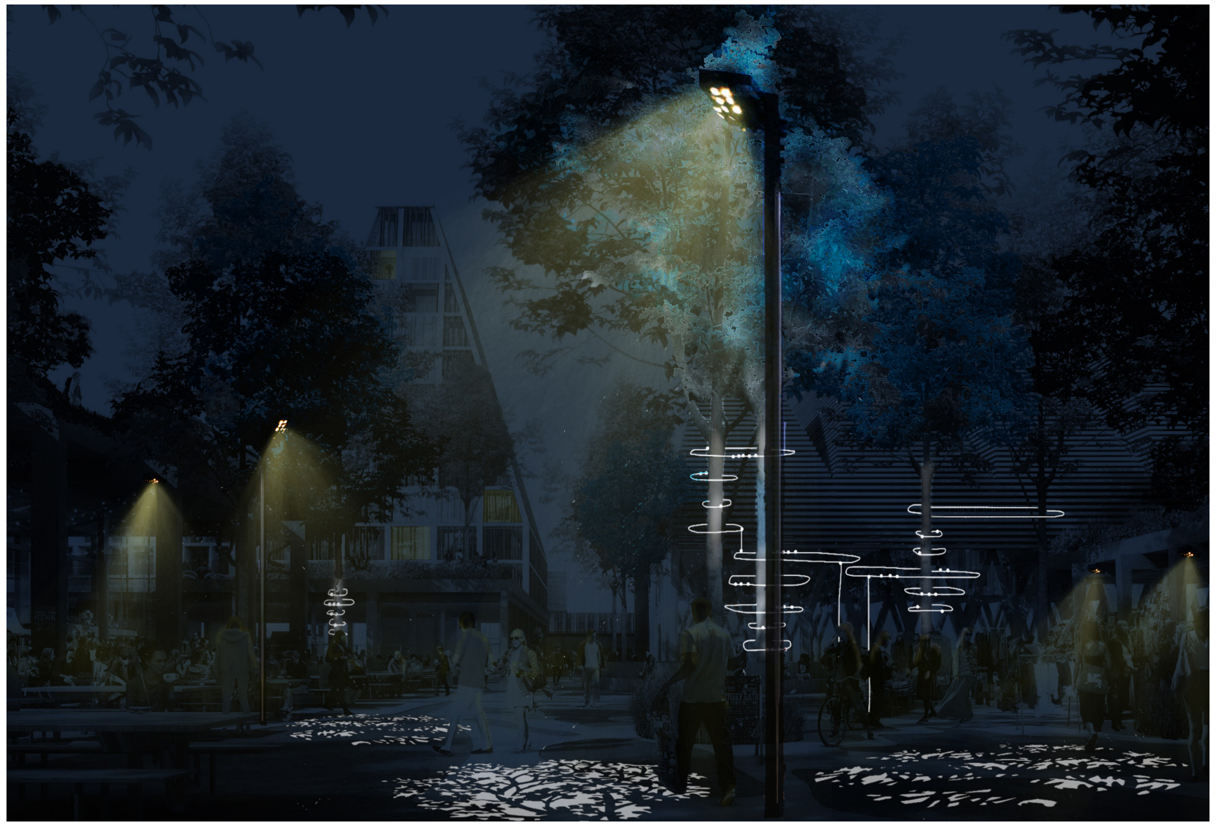


Figure 65
Green interior implementation
Background: (COBE (b), 2016)

5.7 Light Plan

Using the knowledge presented throughout the thesis, the following two A3 landscape orientated pages include the Light Plan. The authors define this Light Plan as an assembly of drawings from floor plans to sections and renderings, used as a communicative tool for the functional and the aesthetic values of the lighting design.

The Light Plan is the final product to be delivered as the output of the Conceptualization phase of the integrated design process. The Light Plan coincides with the Master Plan and illustrates the identities of the blue exterior and the green interior.

Christiansholm 2.0

Element: Blue Exterior

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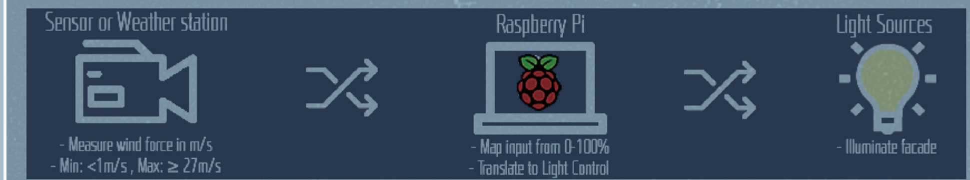
TASK

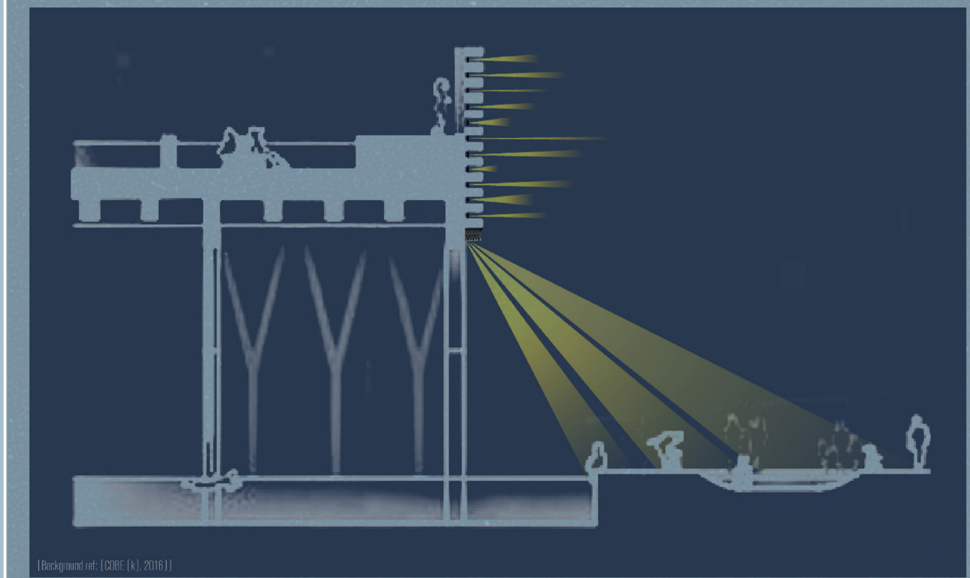
Christiansholm is an island located in heart of the inner harbour of Copenhagen and many people recognize the area today as the Paper Island. An open architectural competition took place in order to gentrify the island from the paper storage industrial halls into new potentials. The winning project by COBE, aims to create a vivid public life that will be balanced with the private life of the future residents. The development is characterised by the "blue exterior" and the "green interior".

IDEA

Analysing the master plan, the idea with this project was to prove the potentials of integrating lighting designers in the design process as early as possible. The aim was to illustrate that it is possible to create an identity by improving the architectural qualities of a given space. This Light Plan consists of the "blue exterior" which coincides with the architecture, supporting the identity of the promenade by illustrating an intelligent facade with integrated light sources, illuminating a strong connection to water.

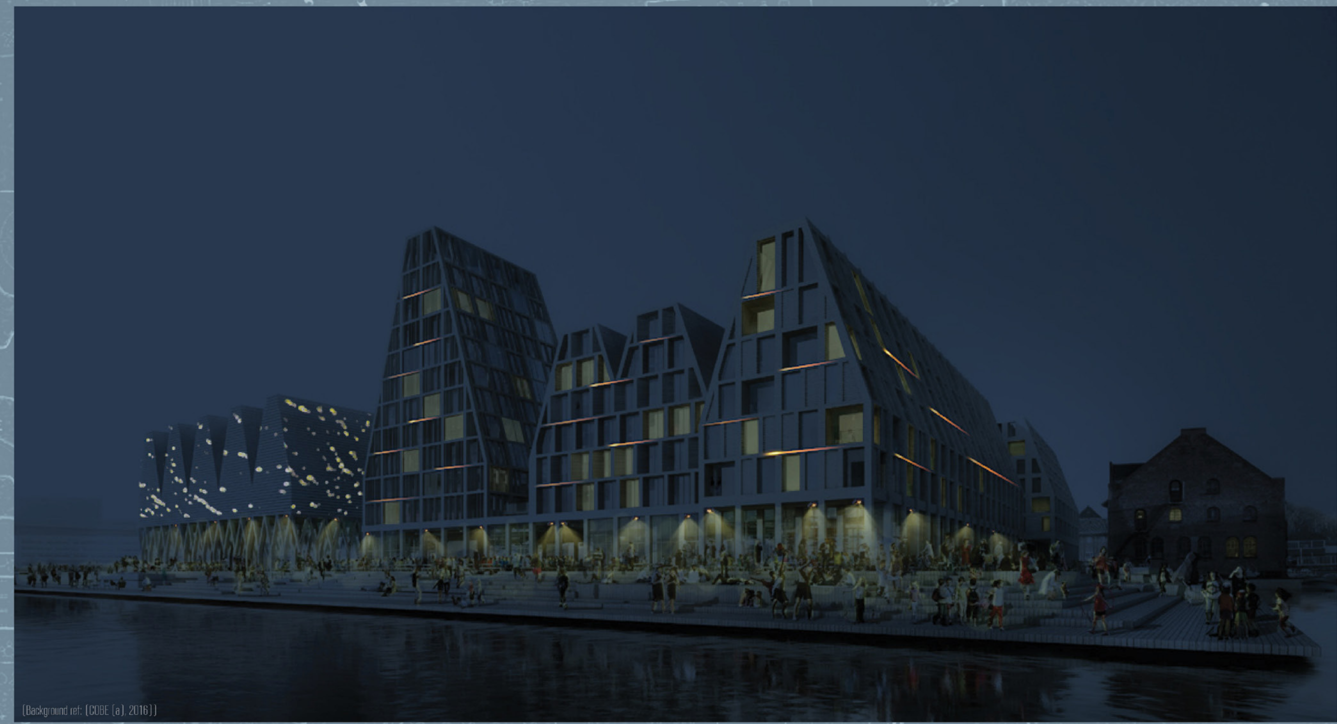
INTELLIGENCE

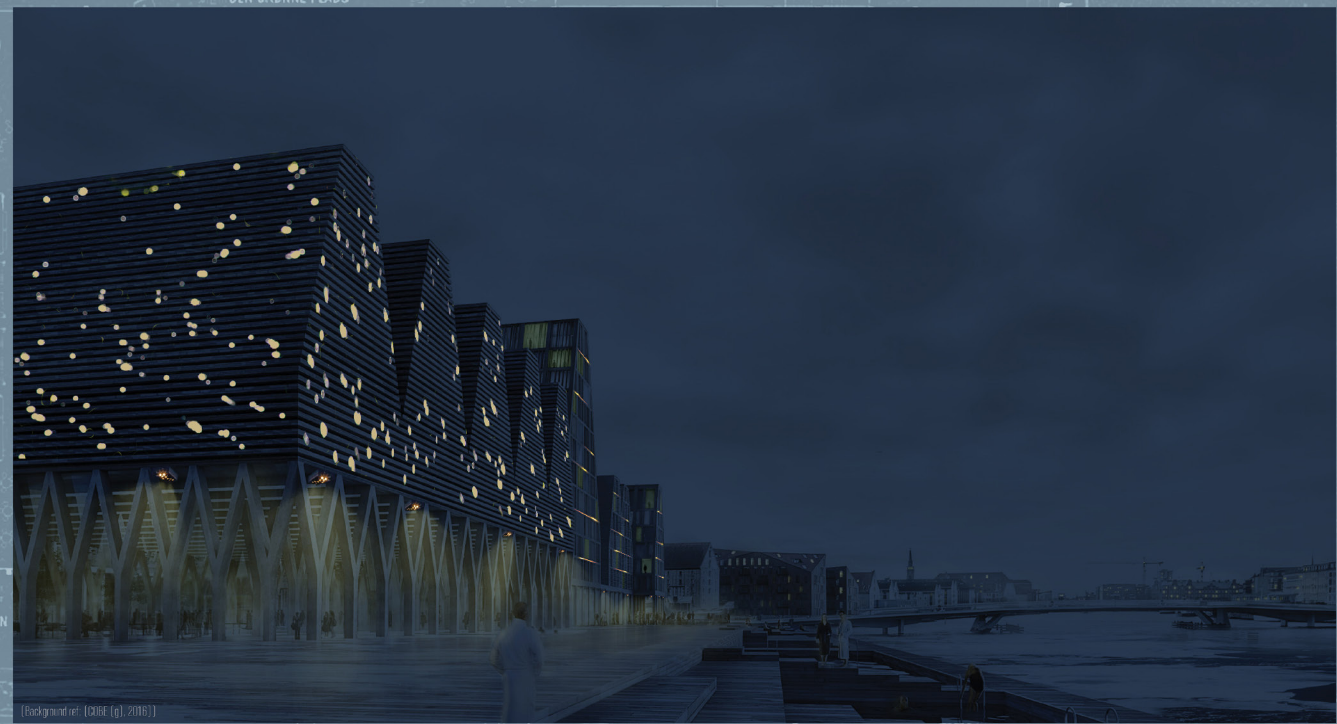




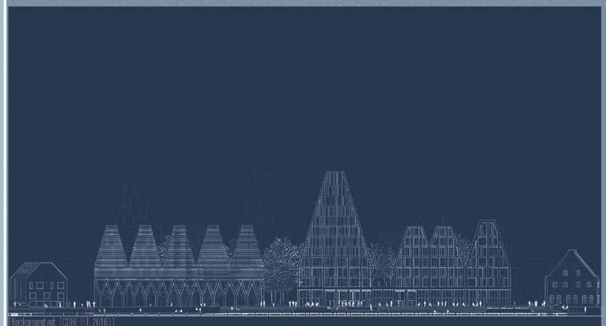
Cross Section of the Swimming Hall Facility illustrating the abstract and discreet LED integrated luminaires and the individually controlled general lighting

PROMENADE RENDERINGS

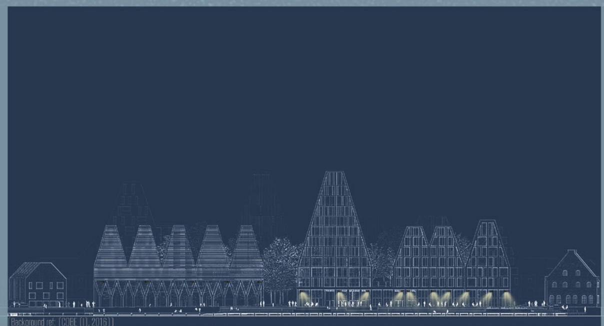




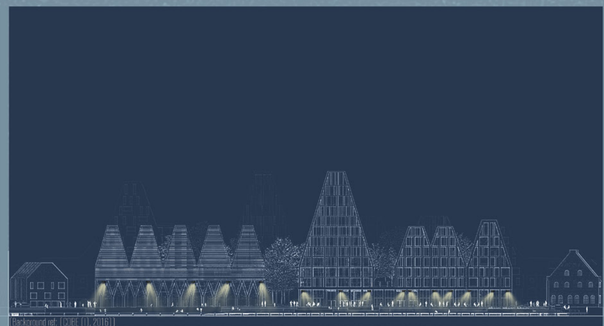
DESIGN



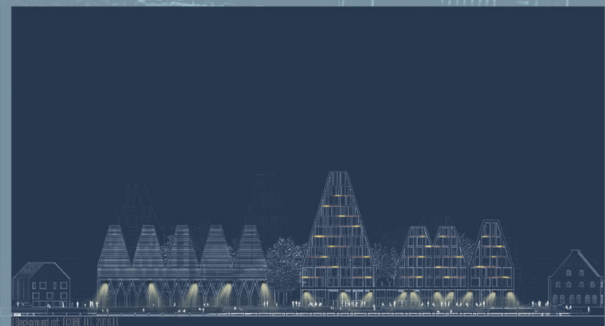
Night time on the north-west facade of Christiansholm without any illumination



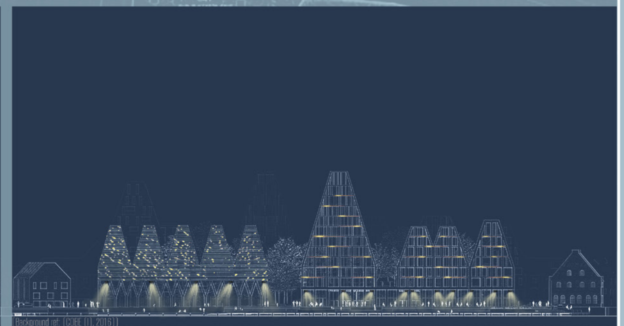
Individually controlled luminaires illuminating the promenade of the multifunctional halls



Individually controlled luminaires illuminating the promenade ahead of the Swimming Hall Facility



LED integrated luminaires imitating water reflection flow on the residential facade



LED integrated luminaires imitating water reflection flow on the Swimming Hall Facility's facade

Christiansholm 2.0

Element: Green Interior

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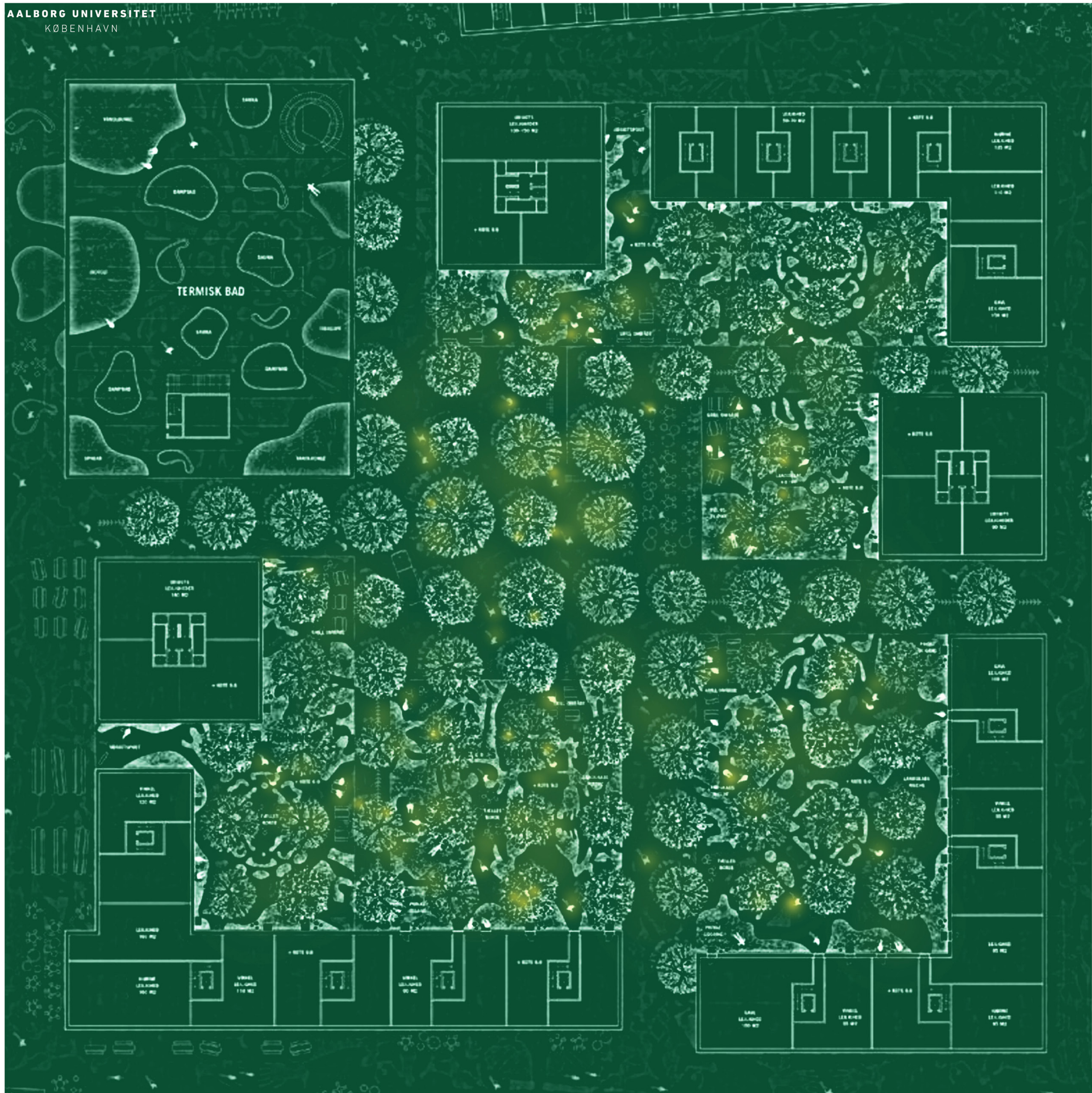
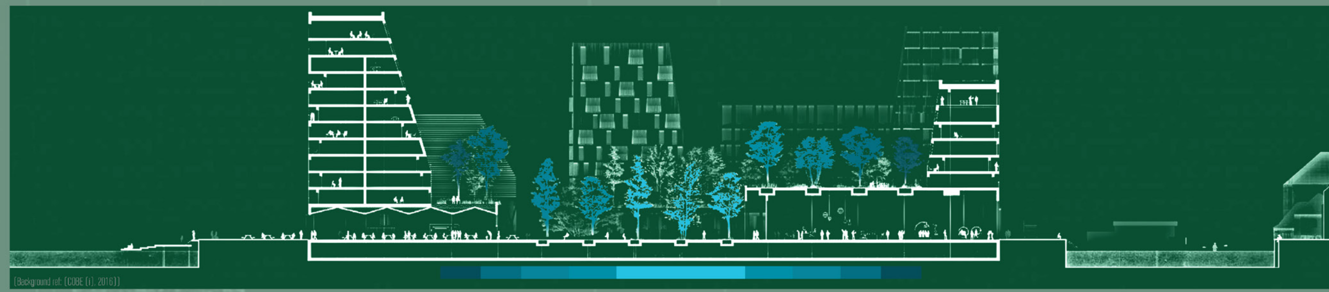


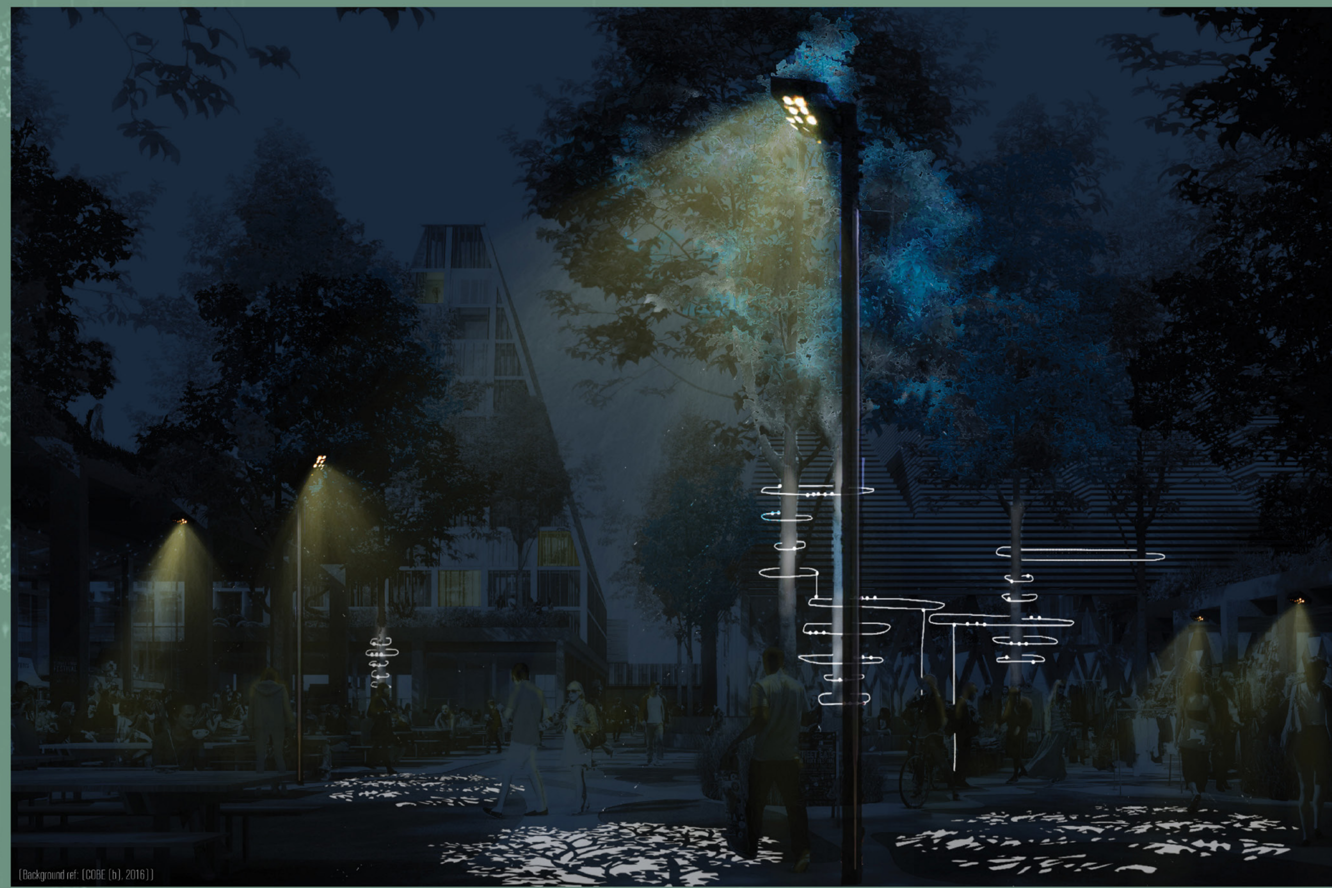
IDEA

Analysing the master plan, the idea with this project was to prove the potentials of integrating lighting designers in the design process as early as possible. The aim was to illustrate that it is possible to create identity by improving the architectural qualities of a given space. This Light Plan consists of the "green interior" which coincides with the landscape, supporting the identity of the green hall by illustrating a light hierarchy of light zones and nature interplay and illuminating a strong connection to vegetation.

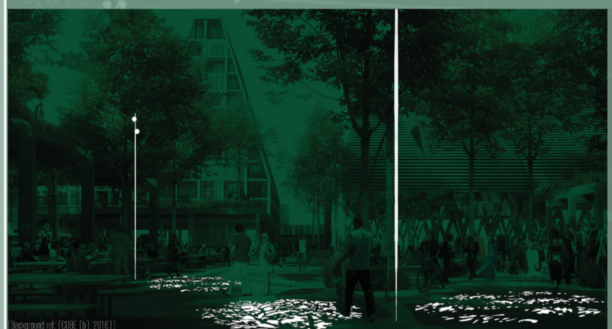
CONCEPT



GREEN HALL RENDERING



DESIGN

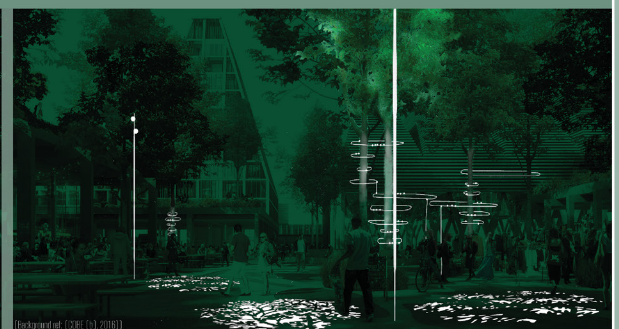


Branch Shadows - illuminating the trees from above supporting their seasonal change

Diversion Zones - illuminating the landscape choices of hardscape and softscape.

Tree Wash - illuminates the trees from below to compliment their trunk texture and tall height

Interactive Plant Light Experience - light and colour respond to the amount of users



Green Hall preliminary design solutions gathered into one holistic lighting design

Chapter 6

Evaluation

6 Evaluation

Coinciding with Chapter *4. Analysis* and *5. Design*, the following chapter will evaluate the overall lighting design and mark the output of stage three in the process model described in Section *3.2. Process Model*. Following the chronological order of the thesis, the chapter will begin with evaluating the success criteria trailing to challenges. This leads to the preliminary design solutions and thereafter the design tests and their hypotheses. Furthermore, evaluation of the lighting design and the Light Plan will be elaborated and concluded lastly through the final problem statement.

In hindsight to Section *5.1 Success Criteria*, the authors took an approach at exploring the following success criteria: *"The blue exterior of Christiansholm should use light as a tool to communicate with its surrounding neighbourhoods through the different facades."*, *"The lighting on the promenade of Christiansholm should introduce a connection between the blue exterior and its surrounding water."* and *"The light sources used in the blue exterior should be discreet and adapted to the structural and material context."*. These three success criteria aimed at developing the lighting design of the north-west elevation of Christiansholm. Simultaneously, the success criteria were closely associated with the challenges of Christiansholm, set to be resolved with the support of the lighting design. For instance, the dullness of the same lighting solution found in the neighbourhood, how to attract visitors from opposite sides of the island and orientation on Christiansholm relate to the success of adding a visually engaging experience, supporting the distinct local identity and guiding with light. These acknowledgements are fulfilled in line with meeting the success criteria of the blue exterior as just mentioned above. It should not go unnoticed that the last two challenges with the highest level of difficulty of encountering others in the green hall and continuing to stimulate the residents of Christiansholm serve the purpose primarily of the green interior and thus need further knowledge exploration. However, the challenge of continuing to stimulate the residents of Christiansholm is introduced by implementing the intelligent system onto the Swimming Hall Facility and residential facades.

To evaluate this knowledge of meeting the success criteria of the blue exterior, preliminary design solutions were developed and tested regarding hypotheses through different methods of 1:1 scale testing and explorative observations. The first experiment of direct versus indirect water reflection presented in Subsection *5.5.1 Water Reflection | Direct versus Indirect*, determined how to communicate water with light accompanying a hypothesis stating that *indirect water reflections create a clear communication of water compared to direct water reflections*. The experiment revealed that indirect water reflection create an easier understanding of the link to water, however, oppose the choice of communicating an abstract and discreet lighting design. The second experiment, blurred versus linear, presented in Subsection *5.5.2 Blurred versus Linear*, investigated if *water reflections as a texture is better understood as moving water from up close than from afar*. The water reflections were studied in forms of video documentation and the results confirmed that moving water from up close is better understood than from afar. Due to the design's aim and investigations of the structural context and light source positions, the blurred reflections was the final choice to design further as it corresponds additionally to an intelligent lighting design. The third experiment, colours of reflection and movement, presented in Subsection *5.5.3 Colours of Reflection and Movement*, investigated if *observing different weather conditions can determine a site-specific colour scheme which supports the characteristics of the space while complying with the surrounding lighting environment*. Partially correct, that the observations of the water conditions did indeed determine a particular colour scheme, the results when placed in the public realm of the surrounding environment proved otherwise. The cool white temperature with tendencies of a blue composition created an unbalance and disrupted the uniformity of the inner harbour of Copenhagen and therefore the result concluded to use warmer white temperature coinciding to the neighbourhoods urban fabric.

Progressing to the implementation process presented in Section *5.6 Implementation*, the knowledge gained from the experiments are transformed towards the Light Plan. The structural understanding of the facades on the north-west elevation provided different possibilities to light source positions. In line with the design aim, the choice was made to integrate the light sources within the minimalistic architecture. Additionally, the intelligent lighting system introduces the flexible possibilities of communicating the knowledge received on the site and being translated into light during the nighttime. The aim reinforced to simulate the existing environment as the amount of movement in the water is based on the effect of the present wind force and water flow, which is also the parameters that affect the light system on the facade. Although the residential facade serves a different function than the Swimming Hall Facility and the illuminated effect is drastically different, the goal stands the same. The north-west elevation is a vital perspective view for different users and must provide a holistic lighting design. Concerning the implementation of the general lighting, the individually controlled system offers a variety of possibilities in controlling the lighting for different structural and material understandings on the promenade. In retrospect to the green hall, further explorations of the preliminary design solutions that are coinciding with its specific success criteria in Section *5.1 Success Criteria* are necessary.

Implementing the Light Plan, in a format as defined by the authors, can be compared to an architectural Master Plan which draws knowledge from empirical material gathered by the experiments and theoretical explorations, illustrated into a visual framework. The detailed plan of the blue exterior and green interior is a bridge towards answering the final problem statement as stated in Section *4.3 Final Problem Statement*: *"Implementing a Light Plan coinciding with the Master Plan can improve the identity of the blue promenade and the green hall."*

The blue exterior in the Light Plan coincides with the Master Plan from COBE and uses the final design introduced in Section *5.6 Design Implementation*, more specifically Subsection *5.6.1-5.6.3*, to improve the identity of the blue promenade. The blue promenade is identified in the Master Plan, and described in Subsection *4.2.1 Blue Identity*, as a space that possesses an eye-catching, active area with outdoor activities. The surrounding water is a strong communicational tool which coincides with the light potentials of the space. These identities are illustrated in the preliminary design solution and further tested and implemented in the final design. By creating an intelligent facade, Christiansholm creates a strong connection to the surrounding water. The integrated lighting solution into the facade is aesthetically pleasing during the daytime as the light sources are hidden and not interfering with the architecture. Additionally, it functions as a tool during nighttime to communicate to the surrounding neighbours in the inner harbour of Copenhagen. The identity of the blue promenade is further improved by using individually controlled general lighting, installed in a discreet manner and adapted to the structural and material context, which functions as a tool, allowing for different outdoor activities on the blue promenade.

Equivalently, the green interior in the Light Plan coincides with the Master Plan from COBE and uses the preliminary design solutions introduced in Section *5.4 Preliminary Design Solutions | Green Interior* to improve the identity of the green hall. The green hall is identified in the Master Plan, as described in Subsection *4.2.2 Green Identity*, as a space that possesses intimate areas with room for events and activities and due to the vegetation, there is a better understanding of seasonal change. These identities are illustrated in the preliminary design solutions by creating different light zones to balance the private and public functions specified for different users and illuminating the vegetation to emphasise the seasonal change. Furthermore, developing an interactive plant light experience attempts at creating a natural transition in the space that will adjust the illumination based on the different users and support a dynamic experience.

Chapter 7

Discussion

7 Discussion

As mentioned in the introduction, there are different types of contracts and agreements and it has not been the aim of the thesis to specify each one nor elaborate on their relevance to the initial problem statement. Instead, the authors will conclude on the knowledge presented in Section *1.2 Traditional Process versus Integrated Lighting Design*. If the thesis followed the procurement method Design-Build as a reference model, the knowledge and findings that have been gathered through the analysis, investigations, design and implementation, would not have been possible to accomplish this early in the project, as this integrated procedure opposes the format of Design-Build. A specialised professional, like a lighting designer, would normally be invited into an architectural project once critical decisions have been taken, related to the scope of the building. This late integration limits the opportunities to create a fully integrated lighting design. The procedure is often the foundation in projects where lighting equipment is out of sync and displays a disruption in uniformity where for instance luminaires have been allocated without a study of the spatial composition.

Christiansholm is in the competition phase, where one can argue that it has specified a set of demands regarding the buildings in the Master Plan. However, as the authors have followed the competition before its public announcement, there was an opening to suggest for implementing an integrating lighting design from the very start. This early involvement in the case study, allowed to build an understanding of the space by critically analysing the architect's material. During the analysis, as lighting designers using trans-disciplinary fields, the authors eyed an opportunity of broadening two elements of green and blue mentioned in the Master Plan, which had a potential to create an identity for Christiansholm. To make the case stronger, the blue exterior and the green interior are further supported indirectly by the municipality of Copenhagen's goals for the future of the capital city. The design was developed based on specific success criteria which are explored through preliminary design solutions, derived from the investigation of existing lighting designs. This knowledge was later tested in 1:1 scale and generated new explicit knowledge.

In this manner, what are the advantages and disadvantages of an integrated lighting design coinciding with the Master Plan in the Conceptualization phase? Could the same result have been reached in a later phase?

The major argumentation to bring forth is that the knowledge derived from the process model in Figure 6 is an advantage to the architects, engineers and the client, as it can be developed in the next phase of the design process. This early involvement influences the design scope of the project for all parties involved as the project evolves and is affected across fields. An example is the facade of the blue promenade, where lighting designer, architect and engineer in a consultation decide on surface structure and materials as a team affecting all parties. For example, changing the material to one with a higher reflectance. This would require less

illumination for the lighting designer, lower power consumptions for the engineer and meeting the rating system of a high certification for the architect.

A disadvantage to an integrated lighting design is the financial expense of granting a mutual salary for all parties involved distributed by the client. This is related to the question of being able to reach the same results in a later phase. Integrated Project Delivery is expensive at the beginning of a project since the decisions are made together between the lighting design, architect and engineer but the costs are reduced later in the process as opposed to Design-Build. If attempting to reach the same lighting design in a later phase, it is theoretically possible but would increase the complexity, as it is not an integrated part of the construction. Either the lighting design would be an added-on installation, or require to take a step back in the construction and demount the already installed elements in order to integrate a lighting solution inside the structure. Using the facade example, if it is chosen to neglect the construction of linear beams on the Swimming Hall Facility and instead develop a flat homogeneous surface. Then the integrated lighting solution inside the hollow beams would in turn become an illuminated projection from a pole, affecting the authenticity and spatial composition of the blue promenade. In turn, the costs would also increase due to the lighting designer working around the decisions that have already been made by the architect and the engineer.

Henceforth, involving a lighting designer into an integrated design process will strengthen the communicative flow as a lighting designer from Aalborg University Copenhagen is capable of communicating with architects and engineers due to the trans-disciplinary master program as presented in Section *1.1 First Generation of Lighting Designers*.

Chapter 8

Conclusion

8 Conclusion

To conclude on the thesis it has been decided to look at the four stages of the Process Model described in Section *3.2 Process Model* and displayed on Figure 6.

When the initial problem statement was formulated in Section *1.4 Initial Problem Statement* for this thesis: *By integrating lighting design in the early design process, it is possible to create an identity by improving the architectural qualities of a given space*, as the outcome of the **Idea Generation** stage, it was a challenge but an informative journey to use the process model to confirm the statement.

Using pedagogical approaches, the **Problem Analysis & Solution** stage defined the potentials of integrated lighting design. This included evaluating the Master Plan and translating that knowledge into a concise final problem statement, as stated in Section *4.4. Final Problem Statement*: *Implementing a Light Plan coinciding with the Master Plan can improve the identity of the blue promenade and the green hall*. It highlighted the architectural qualities of Christiansholm, the blue promenade and the green hall and introduced a tool of communication, the Light Plan, which corresponds to the Master Plan. The investigation of the existing lighting designs that followed brought about influences which were transformed into specific success criteria, applicable for the blue exterior and the green interior.

Moving into the **Design** stage of the process model, the criteria were resolved into preliminary design solutions that were tested and explored concerning hypotheses. The knowledge derived from the experiments was implemented into a final design with primary focus on the blue promenade, which resulted in the Light Plan.

This outcome marked the inauguration of the last stage in the process model, **Implementing Solution**, which generated new explicit knowledge in arguing the advantages of early integrated lighting design. The benefits of lighting designers in an integrated design process are the influences the knowledge will commence to the architects and the engineers while the project is evolving across fields and strengthening the overall design.

Chapter 9

Further Development

9 Further Christiansholm

Due to time restraints, this chapter elaborates on the following suggestions for the future works regarding the lighting design of Christiansholm.

Firstly, the need for a better dialogue with the architecture firm is vital in the discussion of how lighting design can become a more permanent part of the design process. Important information such as material choices and accurate measurements of the buildings and public areas has been kept as internal information but are crucial for the next step in the process in order to determine suitable luminaires. Another future step is to build a physical model of the blue promenade and the green hall to extend the possibilities of developing a demo for testing different lighting scenarios. An example is the Swimming Hall Facility, which has a distinct facade structure that raises experimental potentials of how the intelligent light sources are fitted within the structure. Regarding the virtual world, building a model in a computer graphics program can extend the possibilities of digitally simulating light through rendering and analysing how material choices can be made on the premise of lighting and vice versa.

Secondly, there is a need for further developing the preliminary design solutions regarding the green interior. As a space that balances both private and public functions, tests in 1:1 scale are necessary to understand the potentials of light zones and nature interplay. For instance, exploring a colour matrix that is coherent in its communication to the trees and the sky is an important study for performance variations and how this can stimulate the residence of Christiansholm.

Lastly, following the design process, the next phase in the project thesis is defining light recommendations for outdoor spaces and how this can affect the intelligent and general lighting. These recommendations serve as an understanding of the amount of illumination to provide to each classified area while the integrated lighting design solutions can propose meeting these recommendations all the while respecting the spatial composition and developing a unique outdoor room.

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