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The Moon as a Light Source

New sustainable ways of lighting up cities at night

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Abstract. In our well-lit cities today, light pollution has become an increasing issue and serious threat of natural darkness and the view to a night sky full of stars. Darkness is not only a natural part of the day- and night-time cycle, but it is a basic need for all living creatures. And as light takes over in our night-time environment, this causes issues for both wildlife, nature, and human health. This project thematizes these issues by introducing new perspective on how to create a balanced relationship between human needs for lighting and natural needs for darkness. Through the case of Anholt island, the darkest place in Denmark, this is done by investigating human perception in low-level lighting and the Moon as a natural light source, that can be incorporated in a lighting design. The result is a dynamic lighting scheme, which incorporates the Moon's cycle by turning the electrical light 'on' and 'off' depending on the significance of moonlight. This both in a functional and aesthetical way, which not only protects the darkness but enhances the atmosphere of it, while at the same time supporting human needs for lighting in an urban context.

1. Introduction

According to the International Dark Sky Association, light pollution is characterized as an inappropriate or excessive use of electrical light hindering us to see and experience the night as dark [1]. Nearly all living organisms, including humans, have evolved under a natural rhythm of day and night, and as lighting becomes brighter and more extensive, this distinction becomes blurred [2]. This results in disruption of the human circadian rhythm, causing several health effects, such as cancer, depression, diabetes, and sleep disorders [3, 4]. It also affects the behavioral and population ecology of organisms in their natural habitats including foraging, reproduction, migration, and communication [5]. With the increasing issues of light pollution, it is important that we start searching for new ways of lighting up outdoor spaces at night. We need to create a more balanced relationship between the human needs for lighting and the natural needs for darkness. This is not only to minimize the impact on human health and the natural environment but to simply bring back the experience of the night. Before electrical outdoor lighting, complete darkness characterized the night-time environment together with an undisturbed view of the sky full of shining stars. While the sight of the Milky Way and the experience of moonlight on a full Moon night was a natural part of the night-time environment, these natural wonders are today obscured by light pollution. This means, that one must travel far out of urban areas and into the more untouched places on Earth to experience this fully.

The following article is an attempt to challenge the way we light up cities at night and to provide new perspectives on how we can balance the delicate relationship between light and darkness. Through a case on Anholt Island, the darkest place in Denmark, this is investigated with a focus on the Moon, nature's own light source, and how this can be used as a design tool when designing sustainable outdoor lighting. By investigating the darkest place in Denmark, the intention is to produce knowledge, which can be used when designing lighting at Anholt but also to create an awareness, which can be used in more densely populated urban areas. In larger cities the Moon is visible on the sky, but the human eye

is not able to experience moonlight on urban surfaces because the brightness level from urban lighting is too high. The demands for visibility and safety are higher because of a higher density of people and traffic. But studies show that if brightness levels are balanced between a lit zone and the surrounding lit zone, brightness levels can be lowered. With a holistic approach to our urban lit zones, visibility can be increased by avoiding contrast. Studies show that less contrast leads to a more relaxed atmosphere and an increased feeling of safety because visibility is increased [6, 7]. Lower, more balanced lighting levels can possible also lead to natural dark night experience such as moonlight phase shifts and starry nights, in bigger urban environments than the city of Anholt.

2. Aim

The aim of the project is to investigate how moonlight can be incorporated in an outdoor architectural lighting design to protect the natural darkness, while at the same time supporting human needs for lighting in the town scape of Anholt. The aim is, that this can provide new ways of thinking and designing outdoor lighting, which can lead to sustainable lighting solutions in the future – not only in Anholt, but in cities around the world.

3. Background

The study of this article springs from a Lighting Design Master Thesis project at Aalborg University in Copenhagen. It began in summer 2020 with a field trip to Anholt Island where observations in the town area and interviews with the inhabitants were conducted. Anholt is a small Danish Island with around 130 inhabitants. It is located in the Kattegat Sea, right in between Denmark and Sweden. It is around 50 km. away from the mainland on each side, and it is therefore completely undisturbed by light pollution. The article reveals findings from a case study of Anholt Church, which is located in Anholt town in the centre of the island.

Walking through Anholt town at night, one is overwhelmed by how dark the night really can be. There is only a handful of streetlamps along the narrow streets and a few wall lamps on public buildings to signal the entrance. A bit of lighting is sensed from inside of people's private homes, but besides this, it is completely dark. Looking up, the stars are visible. Not just the ones forming the big Chariot, as we are lucky enough to experience in the rest of Denmark, but also the Milky Way. And the rest of the universe – that is how it seems at least. For a person growing up in urban areas, this simply feels unreal. It is not surprising, that this natural experience of darkness is one of most important elements for the inhabitants living here. They value the darkness deeply; it is part of their identity, and they fight to protect it. Going for a walk to look at the night sky was mentioned by the inhabitants as one of the most appreciated activities. Here they find 'calmness' and 'contemplation' as the informants describe it. Interviewing the inhabitants about their relationship with darkness, it was furthermore interesting to discover, that moonlight plays a significant role in this experience. One informant describes it: "(…) there are bright nights, semi-bright nights, and dark nights. If the Moon is there, either half or full, then you do not need any electrical lighting. Most of the nights are bright. They are illuminated by the Moon and contours are visible. It is completely dark when it is new Moon, and when it is cloudy. This natural change of light and darkness is something I enjoy". Even though the inhabitants enjoy the darkness, they expressed a certain unsatisfaction with the town area when it is dark. This seemed to be connected to the streetlighting, which is described as "obscuring the view to the night sky" and "destroying the impressions of natural lighting and darkness". Besides the experience of lighting being too excessive, the informants also expressed a lack of it. One informant explained that: "It is simply too dark to navigate just a little bit". Another informant also described that the lack of lighting in the town creates a feeling of the place being 'empty' and 'boring' in the darkness.

As a result of the fieldtrip to the island, Anholt church was chosen as a case study for the project based on its social- and visual function in the town. The church is one out of only a few public buildings and it is mentioned as an important local meeting point. Here, the community meets for holidays, anniversaries, concerts, and other communal events. Besides being a central meeting point for the community, the building is literally in the centre of the narrow town. It is small and simple in its

architectural style, but with its unique placement, it is a beautiful landmark visible from the near distance. Through an architectural lighting design, the church has the potential to not only provide visual identity during the day but also during the dark hours. Right now, the church has no electrical light at night, and is, like the rest of the town, 'hidden' in the darkness. By creating a lighting design for this specific place, it would be possible to support visual orientation and atmosphere in the near surroundings of the town, which could hereby lead to a more enjoyable night-time environment for the people living here.
Moonlight became the core of the project based on the local knowledge and experience; that it has exceptional lighting qualities in the darkness providing enough visibility for people in Anholt to see efficiently without any electrical lighting. This specific insight led to the study of how the lighting design at Anholt church can incorporate and interact with moonlight. This is to protect the experience of the night, while at the same time supporting the inhabitants needs for lighting in Anholt town.

4. Design process

The design process involved three steps in the order of 1) a literature review of guidelines on how to minimize light pollution and an extensive literature review of the Moon's phases, illumination levels and human visual perception of it, 2) visualization of lighting scenarios, and 3) an online survey. Each step will be elaborated in the following sections.

4.1. Literature review

4.1.1 Light Pollution Guidelines. As astronomer David L. Crawford explains, avoiding light pollution and the negative effects caused by it, doesn't mean that we need to turn off all electrical outdoor lights at night [8]. Instead, research shows that there are four overall principles to follow; *need, spectrum, intensity,* and *direction,* which together can minimize the negative impact of outdoor lighting [8, 9, 10, 3]. 1. Need: Humans are the only creatures that want light at night [10], and it is therefore recommended to only leave it on and install it, when/where there is a human need for it [9]. 2. Spectrum: Controlling the color spectrum is another essential recommendation. The general rule is to avoid any light that has emissions in the ultraviolet spectrum and adjacent short wavelengths [9]. This has to do with the fact, that short wavelengths of the spectrum disrupt the circadian rhythms in wildlife (and humans) and compared to longer wavelengths this attract many species, which then gets "trapped" in the light [9, 10, 11, 12]. The shorter, blue, wavelengths are also more likely to be scattered by the atmosphere and returned to Earth as sky glow [11]. For these reasons, it is recommended to avoid using light with wavelengths shorter 480 nm ("cold white" or "blue" light) and use amber and "warm white" light with a color temperature of 3000 K. or lower [12]. 3. Intensity: Regarding the intensity of light, it is essential that this is kept as low as possible to avoid disturbing species in the area of the lighting as well as reducing the reflection of light in the atmosphere [9]. The lighting has to correspond to the minimum amount of light required for the given task [8, 9], but in case of designing lighting for natural area, it is recommended to not solely rely on standards created by professional societies since these are generally developed for urban/suburban areas with little to no regards for wildlife. Instead, the efforts should be made to reduce the intensity of lights and still achieve the desired function [9]. 4. Direction: Managing the direction of light emissions is important to reduce impacts to natural lands and species, and to prevent light from shining directly towards the sky [9]. To do this, the light must be directed carefully, so that it will only shine on the target to be illuminated. Besides this, the light source must not be visible at large distances in any direction beyond the target area, and any illumination (including floodlight) must be directed downwards [12]. To reduce glare, it is recommended to install a 'full/sharp cut-off' luminaire, which do not shine any direct light above a horizontal plane that passes through the bottom of the fixture [10].

4.1.2 The Moon. The Moon is a complex phenomenon constantly changing its appearance throughout the month. To incorporate moonlight in a lighting design an extensive literature review of it was therefore conducted. It is important to note, that when we talk about moonlight, it is not the Moon itself

that produces it. The light we experience is instead light from the Sun, which is reflected towards the Earth from the surface of the Moon. The Moon is not always visible on the night sky. It appears at different times, sometimes not at all, and it looks different in both size and shape. This has to do with the natural phases of the Moon. Half of the Moon's surface is always illuminated by the sun. However, the side of the Moon that faces the Earth, the 'near side', only becomes visible to us on Earth through eight different stages [13]. These stages change from one day to the next because of the Moon's orbital motion around the Earth, which takes 27,32 days. When the Moon has completed the eight-stage cycle, it starts all over again [14]. During the first phase, defined as the 'New Moon', the Moon occurs when the Sun and Moon are on the same side of the Earth, which makes it more or less invisible to us in the night sky [15]. As the Moon continues into to the next phases of 'waxing', the illumination from the Sun increases on the surface of the Moon and it slowly becomes brighter until it reaches its peak at 'full Moon'. From here, the illumination decreases as the Moon continues into the phase of 'waning' and finishes its cycle at 'new Moon' again [14].

It is estimated that the light of the full Moon is approximately half a million times less bright than of the sun [14, 16]. However, moonlight provided by full Moon is enough illumination for the dark-adapted human eye to see efficiently in darkness and hereby navigate properly in the night-time environment [17, 18, 8, 19]. The exact amount of light provided, is still uncertain and it is something that scientists continue discussing [20, 9]. In research by Christopher Kyba et al., it is announced, that many existing publications report incorrect values for full Moon illuminance varying between levels of 0.5 lux and all the way up to 2.2 lux [20]. According to Kyba et al., these levels of illumination are far too high and unrealistic, and based on their study of the Moon, they conclude that the full Moon, even at its highest elevation, will only produce between 0.05-0.2 lux on the ground [20]. At rare moments, when the Moon is directly at zenith, the full Moon illumination can be up to 0.32 lux. But as Kyba et al. note, this is only at optimal atmospheric conditions, for a few hours each year, in the tropics [20]. Research by Travis Longcore and Catherine Rich provide the same results of full Moon illumination at a maximum level of 0.3 lux, in rare scenarios, and they furthermore write that in most cases it is closer to 0.1 lux on the ground [21], this is also concluded in research by R. Dick [10]. Regarding the rest of the Moon's cycle, research show that the illumination is significantly less than at its peak at full Moon. Two days right before the full Moon, and two days right after, the illumination is only ½ of the maximum it reaches at its full stage [18]. In the later phase, at 'quarter' Moons, in both periods of 'waxing' and waning, is around 0.03 lux on the ground, and finally it is down to around 0.0013 – 0.008 lux at first and last stage of 'crescent' [21].

Not only does moonlight provide visual orientation at night, but it also creates a unique visual experience of the night-time environment. Despite the fact, that moonlight is a warmer orange-red correlated colour temperature (CCT) than sunlight, around 4100K CCT [22, 23], it is, by the dark-adapted eye, perceived as a cold silvery light with a blue tinge [20]. As Marco Ciocca and Jing Wang describes it: "(…) everything bathed in it [moonlight] looks the same yet different, cold and peaceful." [22]. This is especially significant around full Moon when the Moon is at its brightest. Another unique quality created by the soft moonlight is the significant dark and sharp shadows that it draws in the environment. John Naylor describes it compared to daylight shadows: "In daylight, scattered and reflected sunlight are bright enough to illuminate all but the deepest recesses. At night, only those nooks and crannies that are directly illuminated by moonlight are visible, hence the inky shadows and dramatic contrasts that characterizes a moonlit scene." [14]. The contrast is created due to the fact, that moonlight is much less bright than sunlight, which therefore only cast soft lighting in the night scene. Besides this, the Moon almost act as a point light source, which has no penumbra shadow but instead only a sharp umbra shadow [14].

Based on this literature review, a schema was created to structure and connect the different moonlight parameters (Fig. 1). The schema divides the Moon's cycle into three overall periods called: Bright Nights, Semi-Bright Nights, and Dark Nights. This division is inspired from the inhabitant's descriptions of the changing darkness levels on Anholt. Each period is defined in relation to the Moon's phase, the illumination level, overall definition of human visual perception, and lux level. Through this schema, it

is possible to understand the significance of moonlight in each period. In the further design process, this was used to define the electrical lighting in relation to moonlight.

	Bright Nights	**Semi-Bright Nights**	**Dark Nights**
Moon Phase	Waxing- and Waning Gibbous.	First and last quarter.	Waxing- and Waning Crescent
Moon Illumination	95%-100% (Approx. 5 days a month)	75%-95% (Approx. 6 days a month)	0%-75% (Approx. 18 days a month)
Visual Perception	Good visual orientation and significant experience of moonlight colour and shadows.	Vague visual orientation and less significant experience of colours and shadows.	No/very little visual perception.
Lux Level	0.1	0.05	0.0001

Fig. 1: Schema illustrating Moon phase parameters.

4.2. Visualizations of lighting scenarios

In the 3D software Blender, a model of Anholt church and the surrounding area was created in a dark, moonlit scene. This was used as a tool to visualize the effects of electrical lighting on the church and the interaction that it would create with moonlight.

Three criteria defined the intention behind the lighting design: 1) create ambiance and visual orientation in the immediate surroundings of the church, 2) incorporate the Moon as a natural light source, and 3) ensure a light-darkness balance. With these criteria in mind, the lighting design was built up by two lighting elements, which together create a subtle illumination on the church and in the immediate surroundings. The first element is small spotlights in the window arches, which highlight the main architectural qualities of the church. The second element is a wall washer placed under the eaves to create a soft uniform lighting effect on the façade. The church is completely white, and this lighting will softly reflect from the façade, which provide a delicate ambient lighting to the immediate surroundings. It indirectly provides visibility but also a sense of space and direction when it is experienced from the near distance of the town area. To minimize the impact of light emission in the environment the illumination is directed downwards towards the ground. Besides these two elements, small lights are placed along the path to ensure visual orientation on the ground.

After having defined the core elements of the design, four different lighting scenarios were tested to identify the right balance of it in relation to both functional and aesthetical qualities of moonlight (Fig. 2).

	Scenario 1 2700 K. w. downlights	**Scenario 2** 2700 K. w. uplights	**Scenario 3** 3000 K. w. downlights	**Scenario 4** 3000 K. w. uplights
Bright Night	No Façade Light	No Façade Light	No Façade Light	No Façade Light
Semi-Bright Nights	With/without façade light	With/without façade light	With/without façade light	With/without façade light
Dark Nights	With/without façade light	With/without façade light	With/without façade light	With/without façade light

Figure 2: Figure showing the four tested lighting scenarios.

Each scenario explores the combination of CCT level and distribution of window light, and how each of these combinations is experienced, both functionally and aesthetically, with/without façade lighting at ‘Semi-Bright’ and ‘Dark Nights’. Each lighting scenario is furthermore designed based on the above-mentioned light pollution guidelines to avoid any negative impact of lighting in the environment.

In terms of CCT levels, the goal was to determine aesthetical qualities of the design concerning how the color of the electrical lighting and moonlight plays together on the white surface of the church. The color of the light is defined as CCT levels, which, depending on the Kelvin degree, can appear in a cold blueish or warm orange-reddish color tone. As stated earlier, moonlight is perceived as a cold-silvery light with a bluish tinge, and the intention was therefore to test if the electrical lighting should have a warm orange-red color tone of 2700K CCT, which enhances the experience of moonlight by contrasting

it. Or if it should be a colder bluish color of 3000K CCT, which enhances the moonlight by supplementing it the same color tone. The reason for not using a higher CCT level, which would match the moonlight color even more precisely, is that this contains a broader part of the blue light spectrum, which is not recommended in a dark sky context [12, 11]. Distribution of window lighting was tested to understand if *uplights* or *downlights* would provide a better distribution of light to highlight the big arched windows on the façade, while at the same time provide a 'cozy' atmosphere to be experienced from the outside. In enhancing the cold-silvery moonlight and balancing the right amount of light and darkness in the space, in terms of human experience, it was essential to furthermore test the effect of façade lighting during the different periods of darkness. This, to determine *if/when* this element should be a part of the design.

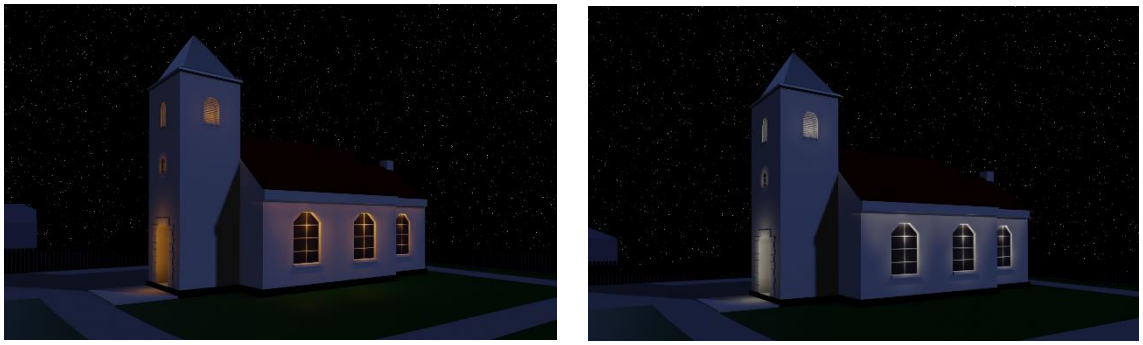

Figure 3: Visualization of lighting scenario 1 (left) and lighting scenario 3 (right) with façade lighting at Semi-Bright Nights.

4.3. Online survey

The different lighting scenarios were evaluated through an online survey, which was sent to the inhabitants of Anholt. Through an image comparison survey, the participants had to choose their preferred design solution and comment on their experience of it. A total amount of 24 people participated. The survey questions were designed to prompt answers about the informants' immediate experience of how the church appears in the darkness and how they perceive the balance with and interplay between the electrical light and natural moonlight. The survey was built up as four steps, where the informants had to 1) 'choose the preferred CCT level', 2) 'choose the preferred distribution of window lighting', 3) 'choose whether it is preferred to have façade light at Semi-bright Nights' and 4) 'choose whether it is preferred to have façade light at Dark Nights'. The questions were formulated as following: 1) 'Imagine that you are out on an evening walk, where the full Moon is shining on Anholt church. Which lighting scenario do you think makes the church stand out best in the darkness?' 2) 'Which lighting scenario do you prefer now?' 3) 'The full Moon has decreased; it creates less lighting on the church and in the environment. Which lighting scenario do you prefer?' 4) 'The full Moon is gone, and it is now completely dark. Which lighting scenario do you prefer?'. As a final step, the informants were asked to comment on their choices and experiences of the design. This step was only optional.

5. Design evaluation

The survey results showed that most participants, 77%, preferred the 2700K CCT lighting scenario compared to the 3000K CCT lighting scenario. In terms of distribution of window lighting, the results showed that most people preferred downlights. This in both lighting scenario 2700 K CCT, where 58% preferred it, and in lighting scenario 3000 K CCT, where 100% preferred it. The results regarding façade lighting were more complex. In the 2700 K CCT lighting scenario the results showed that depending on the type of window lighting people preferred a different solution at 'Semi-Bright Nights' and 'Dark Nights. At 'Semi-Bright Nights' with the downlights lighting scenario most participants, 64%, *did not prefer* the effect of façade lighting. But most participants *did prefer* it at 'Dark Nights', 55%. The opposite situation occurred with uplights at 'Semi-Bright Nights'. In this case most participants, 67%,

did prefer it, and at 'Dark Night' most participants *did not prefer* it, 67%. In terms of the 3000 K CCT lighting scenario the results showed that most participants, 60%, *did not prefer* façade lighting with downlights in neither scenario of 'Semi-Bright Nights' or 'Dark Nights'. Since the participants were not asked to explain their choices, it was not possible to draw deep conclusions about these results. But the results do indicate that downlights function better *without* any façade lighting at 'Semi-Bright Nights', while uplights seems to be more balanced when there *is* façade lighting. At 'Dark Nights', uplights on the other hand seems to be more balanced *without* façade lighting than downlights, which in this case seems to be more balanced *with* this effect. In terms of CCT levels, it is only the 2700 K CCT lighting scenario that seems to work best *with* façade lighting compared to the 3000 K CCT lighting scenario, which seems to be better *without* at both 'Semi-Bright Nights' and 'Dark Nights'.
Based on the survey results and evaluation of it, the final design was defined. The 2700K CCT lighting design got more positive response from the participants and was therefore chosen as the final solution in terms of CCT level. One participant described it as "cozy lighting." Another participant furthermore explained: "The warm lighting is more welcoming; the church appears warmer, and it does not disturb the darkness in the same way as the colder lighting." The intention behind the design was to create atmosphere and orientation. With positive comments, such as 'cozy', 'warm' and 'inviting', this was considered achieved with the 2700K CCT lighting scenario compared to the 3000K CCT lighting scenario, which was perceived as more 'sharp' and 'disturbing' in the darkness. In terms of distribution of window lighting and the effect of façade lighting, the final design solution was chosen to be one with downlights, no façade lighting at Semi-Bright Nights and façade lighting at Dark-Nights. Most people preferred this combination. And taken into consideration how delicate moonlight is, especially at 'Semi-Bright Nights', this solution is also the one, which will ensure the most significant experience of moonlight in the environment.
As a final note it is essential to point out, that the survey is not scientifically significant. Instead, the survey was created to engage the user in the design process and provide an overall indication of their perception of a balanced interplay between the components of electrical light and natural moonlight. The results should be viewed as an initial attempt of developing design principles on how to design with moonlight in an architectural context. Developing the lighting design would involve further, more in-depth, examinations of other parameters such as material, lux levels and placements of light sources. These examinations would also involve being situated in the environment at the different moonlight phases to test the effects of light and materials.

6. Final design proposal

The three-step design process has led to the development of a dynamic lighting scheme for Anholt church, where the electrical lighting is designed to turn 'on' and 'off' depending on where the Moon is in its monthly cycle (Fig.4).

	Path Lighting	**Window Lighting**	**Façade Lighting**
Bright Night	OFF	ON	OFF
Semi-Bright Nights	ON	ON	OFF
Dark Nights	ON	ON	ON

Fig.4: Figure illustrating the dynamic lighting design scheme.

This results in a design, where the use of electrical lighting is limited to when there is an actual need for it. At 'Dark Nights', all three lighting elements are turned 'on' to provide atmosphere and visual orientation in the complete darkness. As moonlight becomes more significant during the period of 'Semi-Bright Nights', the façade lighting turns 'off' to let the delicate moonlight shine 'undisturbed' on the façade and let faint shadows draw visible contours in the space. The warm window lighting will contrast the cold moonlight and hereby enhance its significance. Path lighting is still 'on' at this stage to ensure proper visibility on the ground, but as the Moon moves into the last stage of 'Bright Nights', this is also turned 'off'. At this stage, moonlight is at its peak, and by minimizing the effect of electrical lighting to only window lighting, both its functional and aesthetical qualities can unfold naturally in the space.

Fig.5: Visualization illustrating the final lighting design at 'Dark Nights'. View from the vest side (left), view from the north side (middle) and view from the south side (right).

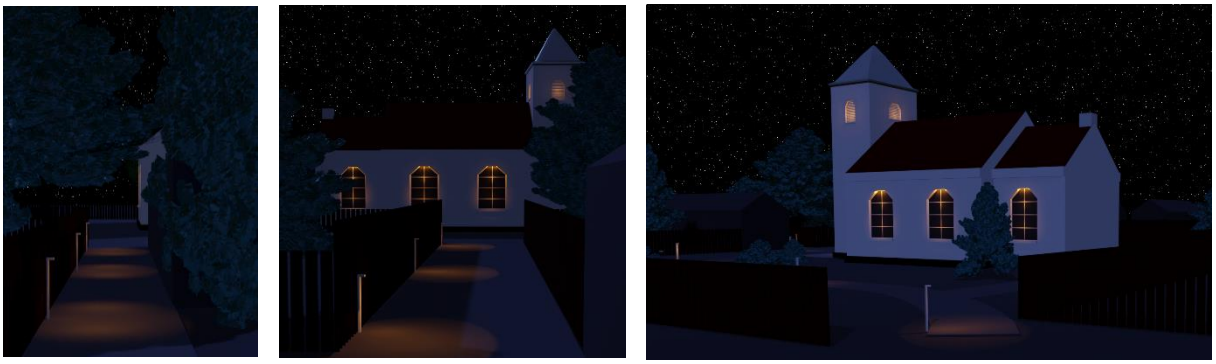

Fig.6: Visualization illustrating the final lighting design at 'Semi-Bright Nights'. View from the vest side (left), view from the north side (middle) and view from the south side (right).

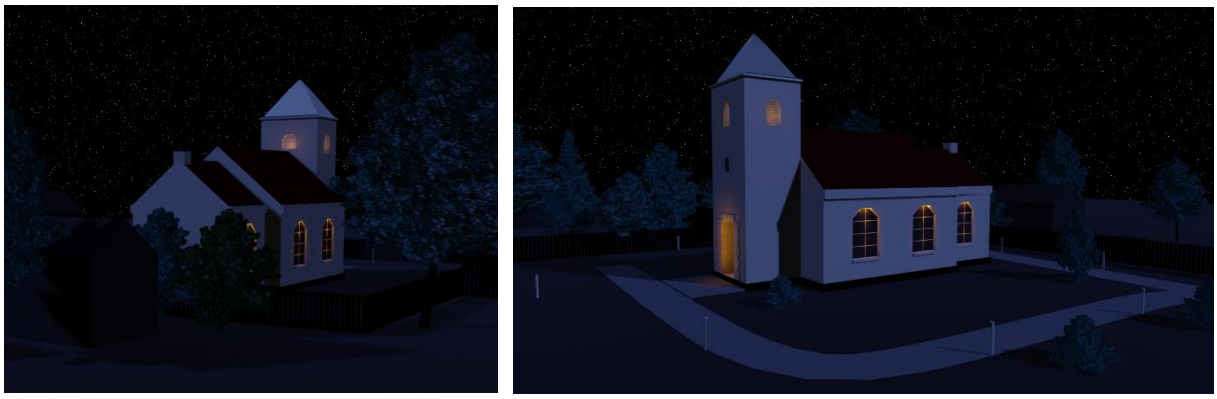

Fig.7: Visualization illustrating the final lighting design at 'Bright Nights'. View from north-east side (left) and view from south-vest side (right).

7. Perspectives

This study stems from a desire to understand why people value living with darkness and shows how a particular sensitivity to the nuances of darkness and thus the power of moonlight can be developed. In this study, Anholt church acts as an example of how this can be done. In future studies, these findings could be developed in relation to the rest of Anholt island in terms of both streetlighting, other public buildings, and lighting in people's private gardens. In future studies it would furthermore be relevant to do field studies with tests of human vision in darkness [19] in relation to the different levels of moonlight.

The case of Anholt church shows an example of how the phases of the Moon can be used as a design element in a night-time environment with almost complete darkness. But can this sensitivity to 'Bright-Nights', 'Semi-Bright Nights' and 'Dark Nights' be transferred to larger, more brightly lit cities? By working with a holistic approach to urban lighting design and by balancing brightness levels between lit zones, brightness levels can be reduced in selected areas [6, 7]. We can create places in cities where it will be possible to regain a lost contact with the naturally created light at night. In cities, we have greater demands for brightness levels due traffic and human feeling of safety, but studies show that by balancing brightness levels and thereby reducing contrasts, a visual contact with spatial and social surroundings can be re-established and thereby a relaxed atmosphere and an increased feeling of safety can be achieved [6, 7].

8. Conclusion

The aim of this project was to investigate how moonlight can be incorporated in an architectural lighting design to balance on the one side natural needs for darkness and on the other side human needs for lighting. The result is a dynamic lighting scheme, where the electrical lighting turns 'on' and 'off' depending on the significance of moonlight.

The findings from this project are not only relevant in the case of Anholt but can act as inspiration for future lighting in bigger cities as well. In a complete dark environment like Anholt, moonlight teaches us, that visual orientation is possible in even the faintest bit of light. If we start taking this into consideration, by simply lowering electrical lighting, we could benefit a lot from this in different ways. Not only would we minimize the issues of light pollution, but it will also let us rediscover the atmosphere of natural darkness and allow us to explore new ways of designing outdoor lighting, that draws attention to and interacts with the unique qualities of moonlight.

The starting point for the design at Anholt church was not lighting but instead darkness. In the beginning of a design process, we should start changing perspective and instead of asking ourselves how much lighting we need, we should focus on darkness and ask ourselves how much we can *minimize* lighting to protect the darkness while still supporting functional and aesthetical needs.

Lighting Designer François Jousse describes it beautifully: "The secrets are very simple. Blend light with the surroundings. Don't annoy the birds, the insects, the neighbors, or the astronomers. If City Hall gave me money to do whatever I want, I'd teach people about the beauty of light." [25].

6. Acknowledgement

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