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Lighting as a service:
Functional and aesthetic factors applied to retail spaces

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Lighting as a service:

Functional and aesthetic factors applied to retail spaces

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Abstract

The lighting industry has not only approached circularity within production of luminaires but also in contemporary time introduced a model of service that uses circular principles, lighting as a service (LaaS). Lighting as a service offers clients a leasing contract of luminaires including maintenance, upgrades and repairs. The concept is yet new and not very established to suit all fields.

This thesis is focused on visual aesthetics and functional factors of lighting as a service in relation to clothing retail spaces. Lighting design has an important role for clothing stores' representation of products and customer’s experience which makes a complex relation between retail lighting design aims and lighting as a service to cohere. Methods used in this thesis includes site-visits to evaluate retail lighting qualities of various stores in Stockholm city, two case studies of earlier documented lighting as a service project that’s evaluated through two separate SWOT-analyzes. This to investigate principles of lighting as a service, visual aesthetics and functional factors and the possibility to practice the service in clothing retail spaces. The result is presented in written form and a 3d model made in the software program DIALux evo.

Keywords: Lighting as a service, lighting design, retail, circularity, circular economy.
Acknowledgment

I want to thank my tutor Kristian Renström for sharing his valuable expertise and inspiration for the growth of this thesis. I would like to thank my teachers at KTH: Rodrigo Muro, Foteini Kyriakidou, Federico Favero, Ute Besenecker, Gerhard Rehm for all the support, knowledge and feedback that has been shared this year. Last but not least, my friends and family whose time and support have been invaluable.
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1. Introduction

Since my bachelor in product design I’ve been taught the environmental benefits of a circular economy and the importance of closing the production loop. When encountering the concept of circular lighting during my studies at KTH I became interested to investigate the concept further.

According to the European parliament, circular economy is a model of production and consumption. The aim of a circular economy is to extend the life of a product and eliminate waste as much as possible. The circular model’s approach involves reusing, leasing, repairing, recycling and reducing energy, waste and raw materials to retain the product’s value. To the opposite of a circular economy, the value of the product is gone after disposal in the linear economy model where the product is produced using new material, consumed and then disposed of in a “take, make, consume, waste” approach (European parliament, 2021).

This master thesis investigates visual aesthetics and functional factors of lighting as a service applied to clothing retail spaces, as well as environmental advantages of lighting as a service. Both the lighting and clothing industry has for a long time used the linear model of production but the interest of shifting into a more circular economy has increased and started to be more considered. However, in the Sustainable Future Report 2022 by NBS, 608 construction professionals were asked in a survey how often their projects they worked the last 12 months had sustainable outcome targets. The survey showed that 25% had it some of the time meanwhile only 14% had it all of the time (NBS, 2022). The survey also showed that professionals with knowledge and confidence in sustainability are more likely to pursue sustainable outcome targets (NBS, 2022). Stated in a mail conversation in May 2022 with Roger Sexton, part of the senior leadership team at Stoane Lighting, that the lack of awareness is the biggest obstacle, not only for lighting as a service, but generally to net-zero design within the built environment (Roger Sexton, 2022 b).

![Circular Economy Diagram](image1.png)

![Linear Economy Diagram](image2.png)

Fig. 1 & 2  Circular economy (left), linear economy (right).
2. Objectives

According to the United Nations Environment Programme, The fashion industry is responsible for 8-10% of global carbon emissions (UN environmental program, 2019). There’s an interest among clothing brands to aim for a more circular production model (Ellen Macarthur Foundation, no date). An example of a local advocate for circularity within the clothing industry is the Swedish outdoor brand Houdini who produced their first product with recycled and recyclable fibers in 2007 and have a goal of a 100% circular collection by 2022. In 2030 they want their whole ecosystem 100% circular, including material, production, knowledge flow, value chains and usage of products (Houdini, no date). If more clothing brands follow Houdini’s example with an aim to transform into a 100% circular ecosystem in the near future there will most likely be an increased demand for circular principles, eventually reaching circular lighting and lighting as a service for their stores.

The aim for this thesis is to investigate whenever lighting as a service can be applied to clothing retail spaces and how it affects visual aesthetics and functions, if it can cohere with lighting design aims and strategies and what environmental advantages there are in the practice. The main research question is:

- How can lighting as a service principles and retail lighting design aim and strategies cohere in clothing retail spaces to promote visual aesthetics and functions?

Followed by one secondary research questions:

- What are the environmental advantages of lighting as a service and how can these be considered in clothing retail spaces?

2.1 Global sustainable goals

In relation to UN’s 17 Global Goals and Agenda 2030, this thesis is focused around following goals:

- #7: Affordable and clean energy: “Renewable energy solutions are becoming cheaper, more reliable and more efficient every day. Our current reliance on fossil fuels is unsustainable and harmful to the planet, which is why we have to change the way we produce and consume energy. Implementing these new energy solutions as fast as possible is essential to counter climate change, one of the biggest threats to our own survival.” (The Global Goals, no date a)
- #12: Responsible consumption and production: “Our planet has provided us with an abundance of natural resources. But we have not utilized them responsibly and currently
consume far beyond what our planet can provide. We must learn how to use and produce in sustainable ways that will reverse the harm that we have inflicted on the planet.” (The Global Goals, no date b)

Goal #7 includes target 7.3: “By 2030, double the global rate of improvement in energy efficiency” (The Global Goals, no date a). The invested case studies in this thesis has shown that lighting as a service and correctly placed luminaires can decrease energy consumption (Tim McManan-Smith, The Energyst, 2014), which promotes this goal.

Goal #12 includes target 12.2: 12.3 “By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse” (The Global Goals, no date b). This target goes hand in hand with the circular economy’s approach of reusing, leasing, repairing and recycling (European parliament, 2021).

3. Background

3.1 Circularity within the lighting industry

This thesis is mainly focused on lighting as a service. However, circularity within the lighting industry can be approached in two ways.

- Circular lighting within production - luminaries components are designed to be disassembled, recyclable and replaced when broken. When recycled, the material can be used again in production and therefore its value remains (Roger Sexton, 2022 a). An example of a lighting manufacturer who follows this model is Stoane Lighting who has since their establishment in 1995 applied the idea of circular economy into their production. (Stoane Lighting, no date a). Through their modular ZTA range they built a concept which allows luminaire components to be repairable, upgradable and recyclable (Stoane Lighting, no date b).

- Lighting as a service (LaaS) - the client can lease luminaires from a lighting manufacturer/service supplier instead of owning them, whereby the lighting manufacturer/service supplier maintains, upgrades and repairs luminaires during a specific time period according to the client’s needs. The inclusion of services and period of time varies and depends on the contract (Philips lighting, no date). Lighting as a service doesn’t necessarily include luminaries made from a circular production.
In 2021 The Chartered Institution of Building Services Engineers (CIBSE) issued a publication with the intention to provide guidance for circular lighting in the industry (CIBSE, 2021). CIBSE publication suggest multiple factors foward, such as innovation made by suppliers and client-led demand. There’s also a need to spread knowledge and information about the circular economy in the lighting industry to promote development (CIBSE, 2021).

3.1.2 Lighting as a service

The first lighting as a service tailored contract within lighting was made by the National Union of Students (NUS), a confederation of student unions in the UK defending student’s rights (National union of students, 2022), and Signify (then Philips lighting) in London 2012. A 15-year contract was made where NUS would pay Signify a fee quarterly and electricity usage while Signify would provide the best and newest technology within LED lighting, provide service for maintenance and reports on the electricity usage. (International Institute for Industrial Environmental Economics, 2014).

Bollnäs municipality in Sweden decided in 2018 to start leasing recycled lighting within their premises, mainly schools, and became the first municipality in Sweden to use lighting as a service delivered by the Swedish supplier Brightco (Brighteco, 2020). These two cases are further explained in chapter 5.2 Case studies.

3.2 Retail lighting design aims and strategies

The role of lighting in retail has various functions, both practical and visual. Lighting can promote navigation and spatial recognition, highlight products to increase attractiveness and facilitate product browsing. In terms of visual aesthetic, lighting can define concepts and brand identity, create an interesting atmosphere and experience that influences the customer’s behavior and mood (Pia Markkanen, 2013). Stores are in need of regular change and give customers the impression that something is happening and new products are available. Rotation of interior and flexible lighting solutions that can be adaptable to new scenarios are important (EEF, 2009). A study from 2012 about customers perception and preferences made by Prof. Jan Ejhed, Prof. Dr. Roland Greule, Markus Felsch and the lighting manufacturer Zumtobel present some key factors of reatil lighting design (Jan Ejhed, Roland Greule, Markus Felsch, 2012).

- Contrast and accent lighting: lighting should be high in contrast to make perception clearer and increase levels of attention instead of increasing brightness in the store which also increases energy consumption. Accent lighting can create contrast and a variation in light
levels. It can also make products stand out from the general homogeneous light and improve its attractiveness (ibid).

- Orientation: vertical lighting can facilitate orientation in the store as well as delimiting the outer areas of the store (ibid).
- Color and color temperature: cool color temperature lighting provides more sense of spaciousness while warm temperatures makes the impression of space smaller and gives a sense of familiarity and safety. There’s a preference for variation in temperatures, for example using different temperatures for general lighting to vertical lighting (ibid).

Using light according to needs is not only important for visual stimuli, according to an article from 2010, lighting formed in a typical grid-based system is accountable for nearly 20% of the total energy production worldwide (Yao-Jung Wen, Alice M. Agogino, 2010)

During a discussion with Kristian Renström, sales manager at Norlux with a focus on retail, Renström made the point that visuality of retail lighting is not fully included in the circular model but efficient light sources and properly oriented luminaires can affect it. For example, when multiple luminaries create a result that could be achieved with lower number luminaries and thereby reduce energy consumption. Renström advocates lighting control to locally control lighting divided into zones within the retail premises. Lighting can be dimmed down when there’s an absence of customers in a certain zone which facilitates energy savings. The biggest mistake within retail lighting today, according to Renström, is increased brightness. High light levels and glare is mostly caused by lack of information about the negative effects of too much light among retailers (Kristian Renström, 2022 a).

To investigate Renströms statement, lux levels were measured during site visits in different clothing stores in Stockholm city, whereby 4 out of 8 stores exceeded the recommended levels for general areas (minimum 300lx, maximum 750lx). The recommendations are based on the European and Swedish standard SS-EN 12464-1:2021 (Ljuskultur, 2022).
4. Methodology

This master thesis is research questions based and process driven. The investigated research findings and its relations influence the result, conclusion and discussion.

![Methodology chart](image)

Fig. 3 Methodology chart.
1. Background research: Literature/articles are used to investigate previous practices and principles of lighting as a service, retail lighting design aims and strategies and to find documented projects of relevance. Interviews/conversations are necessary to gain further knowledge from people who have an expertise in aforementioned topics to get their perspective and experiences.

2. Case studies (Qualitative): The aim of the case studies is to investigate the lighting as a service projects 1. Signify and NUS and 2. Brighteco and Bollnäs municipality to understand principles, needs, relations, aims, successes and mistakes. Both of the projects have similarities of introducing lighting as a service into new contexts. The case studies can provide understanding about the novelty of the concept and what possible challenges that can occur when introducing the service into clothing retail spaces. The studies correspond to both the main and secondary research questions.

3. SWOT-analysis (Qualitative): Used to evaluate the two case studies based on strengths, weaknesses, opportunities and threats in their projects. This facilitates comparison of similarities and differences of advantages and challenges in lighting as a service and how these can cohere to retail lighting spaces, this step will identify common needs. The analysis corresponds to both the main and secondary research question.

4. Site-visits (Qualitative): The aim is to observe how contemporary clothing retail lighting is designed and investigate the qualities and strategies of lighting, for example contrast, products representation, lighting in relation to interior and what is noticeable when entering the store. The observation will be evaluated on the previously mentioned study as a guide, made by Ejhed, Greule, Felsch and Zumtobel (Jan Ejhed, Roland Greule, Markus Felsch, 2012). This step corresponds to the main research question and will be used as an inspiration for the concept development of the 3d model in the result.

5. Common needs: Case studies, SWOT-analyses and site-visits will identify common needs of lighting as a service and clothing retail spaces whereby visual aesthetics and functional factors will be considered. The common needs found will be visually demonstrated in the result’s 3d model.

6. Result & discussion: The result will include a 3d model of a general clothing retail space made in the software program DIALux evo. The criterias for the 3d model is to promote and support the store's visual aesthetic concept and functions while also following lighting as a service principles. The design process of the model will be finalized in based on following order:

   a. Common needs found in the analysis chapter will be solved and transformed into design solutions that consider visual aesthetics and functional factors.
b. Choice of business, concept, materials and interior details will be inspired by the site-visits.

c. The design solutions based on common needs will be applied in the 3d model to visually demonstrate what lighting as a service in a clothing retail store could look like in line with the store’s business and concept.

d. The 3d model will be based on the previously mentioned study as made by Ejhed, Greule, Felsch and Zumtobel (Jan Ejhed, Roland Greule, Markus Felsch, 2012) in terms of lighting solutions and qualities.

e. Energy consumption will be calculated and lighting will be maximized in order to promote the global sustainable goals and follow the lighting as a service principle of low energy consumption.

The result will also include a written conclusion about environmental advantages of lighting as a service in relation to retail clothing spaces based on the SWOT-analyses. The discussion will include clarifications and considerations of lighting as a service application to retail clothing spaces in the future.

4.1 Limitations

This thesis is limited to clothing retail spaces. The outdoor brand Houdini was contacted for an interview in relation to this thesis but needed to decline due to lack of time. The result is therefore presented in a smaller, general space to demonstrate an application that is further adaptable to other premises. A general space is defined as oblong with the entrance on the shorter side without daylight, referring to store spaces in a mall where the premises usually are deep rather than wide. This thesis is focused on factors concerning circular economy, despite the fact that there’s multiple strategies and methods to approach sustainability in various forms.

Fig. 4 Sketch based on a portion of a plan of a mall in Stockholm.
Examples of general, oblong spaces with the entrance on the shorter side without daylight.
5. Analysis

5.1 Site-visits

The aim of the study-visits are to observe qualities and lighting strategies with the previous mentioned study in mind, made by Ejhed, Greule, Felsch and Zumtobel (Jan Ejhed, Roland Greule, Markus Felsch, 2012).

Fig. 5 & 6 Store A/Fashion store in Stockholm city. This store represents a strong concept. It can be assessed by having a younger feminine target group with trend-awareness. The store itself is eye-catching from the outside with multiple luminaries at the entry (see fig. 5) that creates a brighter entrance area. The reflective interiors increase the amount of impression, as well as reflective light. The multiple impressions compete with products of the customer’s attention. The contrast is low which makes the perception of the space unclear, referring to aforementioned study (Jan Ejhed, Roland Greule, Markus Felsch, 2012).
Fig. 7, 8, 9, 10 Store B/Fashion store in Stockholm city. This store has a younger feminine target
group that invites the customer with a pink neon lighting concept that continues throughout the store
in forms of lettering and arrows (see fig. 7 and 8, top images). The pink also becomes an accent color
to the more neutral toned interior. Based on key factors from aforementioned study, the store lighting
create contrast that separates general areas with displayed areas and provides a focus on the products
and a sense of spatial recognition in the store through lighting on textile drapery that provide vertical
luminance (see fig. 9 and 10, bottom images) (Jan Ejhed, Roland Greule, Markus Felsch, 2012). The store’s overall lighting is mostly spotlights, other general lighting is minimal.

**Fig. 11 & 12** Store C/Sport store in Stockholm city. The store is bright and gives an energetic atmosphere. The multiple spotlights occasionally glare the customer while moving through the store which disrupt the customers attention of the actual products. As seen in fig. 11, fixed general fluorescent lighting overlaps with the spotlight’s accent lighting that is directed from behind the mannequin, creating a shadow under the mannequin’s face and body while shadowing its displayed top. The store offers various sports products and brands for different ages which could be a reason for the versatile store concept to fit a broader audience.
Fig. 13 & 14 Store D/Outdoor store in Stockholm city. Based on key factors from aforementioned study, the store highlights their display areas and thereby the contrast shifts focus to the products and provides a clear perception (Jan Ejhed, Roland Greule, Markus Felsch, 2012). The brand uses literal and landscape images as landmarks to envision and inform customers about the product. The shoes are displayed with a light colored background making the dark colored shoes stand out from the interior. The brand’s target group is quality conscious and in a broader age. The overall atmosphere emits a sense of genuinity and the lighting provides a soft transition between general and display areas.

Fig 15, 16, 17, 18, Store A, B, C & D in black & white. Studying the photos in black & white besides each other shows how the contrast and perception differs in the store. The perception of Store A and Store C is less clear, compared to Store B and D.
5.2 Case studies

The two studies are referring to the light as a service projects 1. Signify and NUS and 2. Brighteco and Bollnäs municipality. Both of the projects have similarities of introducing lighting as a service into new contexts. The case studies can provide an understanding about the novelty of the service and what possible challenges there can be of introducing the service into clothing retail spaces for the first time, as well clarify principles and possible visual aesthetic and functional factors.

5.2.1 Case study - lighting as a service: Signify & NUS

**Aim and approach:** NUS' envisioned a future to inspire students by becoming one of the most sustainable offices in the UK, so when they moved to their new office premises in 2012 they wanted to incorporate more environmentally sustainable aspects into the planning, including decreasing carbon emissions and energy consumption. Signify (then Philips lighting) was the only lighting company NUS contacted that was open to discuss the pioneer lighting service model according to Jamie Agombar, then ethical and environmental manager at NUS (Tim McManan-Smith, The Energyst, 2014).

“As a registered charity we didn’t want to own services like the lighting; our priority was to ensure the lighting performed as required in terms of light levels and energy consumption. So we approached a number of lighting companies with a proposal for a cradle-to-cradle rental scheme. Philips was the only one that was prepared to discuss ways of doing business differently.” - Jamie Agombar (Tim McManan-Smith, The Energyst, 2014).

A 15-year contract was made between Signify and NUS in 2012. NUS pays a fee quarterly and electricity usage and Signify would provide the best and newest technology within LED lighting, provide service for maintenance and reports on the electricity usage (International Institute for Industrial Environmental Economics, 2014).

**Environmental and financial:** In an interview from CNBC in 2018, six years after the partnership started, Jaime Agombar, then head of sustainability at NUS, said that NUS has been able to make other sustainable investments such as solar energy installation and water harvesting thanks to the financial savings of renting lighting from Signify rather than NUS owning them (Elizabeth Schulze, CNBC, 2018). The first installed lighting containing 784 lighting points in 2014 showed to consume as low as 5.9W/m² thanks to only using light where it’s needed using various lighting controls linked to occupancy sensors and daylight (Tim McManan-Smith, The Energyst, 2014).
Challenges: The novelty of the project and the contextual based contract includes risks which could be a challenge due to unpredictable happenings that can conflict with terms. This requires good communication and flexibility from both sides (International Institute for Industrial Environmental Economics, 2014).

5.2.2 Case study - lighting as a service: Brighteco & Bollnäs municipality

Fig 19. Premise in Bollnäs municipality. Photograph by Brighteco.

Aim and approach: Bollnäs municipality’s drive for lighting as a service was to be part of a lighting solution that consumes less natural resources, provides a sustainable economy and working environment. The project started in 2018 where the service was supplied by Brighteco in some school premises. The general response of the service has been positive and the municipality has extended the amount of leased lighting each year since then (Brighteco, 2020).

Environmental and financial: A positive aspect according to Bollnäs municipality is that they no longer need to invest in lighting themselves, instead paying a yearly fee to Brighteco and therefore always know what expenses to come (Brighteco, 2020). During a conversation in April 2022 with Joel Smedberg, CEO of Brighteco, Smedberg enhanced the value of right lighting at the right place and stated that municipalities do calculation of lighting and energy costs but not the cost caused by low quality lighting and health issues it can cause. According to Smedberg it’s hard to say if Bollnäs municipality made economical profit from their service because of the complexity of calculation and
comparison (Joel Smedberg, CEO Brighteco, 2022). Another municipality that used Brighteco’s light as a service in 2020 after Bollnäs is Tierp municipality. Tierp found difficulties in the procurement of the service but mentioned that thanks to Bollnäs municipality’s previous experience they could share and provide information to them (Brighteco, 2021).

**Challenges:** Smedberg stated that there’s been minimal error and repair since the project started in 2018. Bollnäs municipality has a somewhat flexible contract which includes a limited amount of adjustment each year. The changes Brighteco implemented on lighting has been due to refurbishment of the premises or change of an activity in space. In this case Brighteco interviews Bollnäs municipality of their needs in these new spaces to provide right lighting (Joel Smedberg, Brighteco, 2022).

**5.3 SWOT-analysis**

The SWOT-analyzes evaluates advantages and challenges of the two investigated case studies and categories findings into strengths, weaknesses, opportunities and threats. This presents key points of lighting as a service in the specific cases and makes it possible to compare similarities and differences of the two cases. This can help to identify common needs of lighting as a service and clothing retail spaces.
### 5.3.1 SWOT-analysis - Signify & NUS (5.2.1)

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<tr>
<th>Strengths:</th>
<th>Weakness:</th>
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<tr>
<td>• Drive: NUS had a strong drive and purpose for the project's outcome and were the ones approaching Signify, making the project possible in the first place.</td>
<td>• Establishment: The service was unpracticed in office areas in the UK making the project's outcome unpredictable. NUS mentioned how a number of lighting manufacturers turned down their proposal before reaching Signify.</td>
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<td>• Environmental goals: The projects helped the NUS to move forward towards their environmental goals of being the most sustainable offices in the UK.</td>
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<tr>
<td>• Energy savings: Thanks to quality lighting, lighting controls and optimizing by only using light where it’s needed, the installation showed a consumption as low as 5.9W/m² in 2014.</td>
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<th>Opportunities:</th>
<th>Threats:</th>
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<tr>
<td>• Financial savings: Thanks to financial savings by renting lighting instead of owning them, NUS got the opportunity to make other sustainable investments for their future such as solar energy installation and water harvesting.</td>
<td>• Communication: The case study showed the importance of engagement and communication throughout the project. Signify needed to regularly update NUS on electricity usage and new technology according to their contract. Miscommunication could affect the project negatively.</td>
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5.3.2 SWOT-analysis - Brighteco & Bollnäs municipality (5.2.2)

<table>
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<tr>
<th>Strengths:</th>
<th>Weakness:</th>
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<tr>
<td>• Drive: Bollnäs municipality wanted a lighting solution that consumed less natural resources, provided a sustainable economy and working environment.</td>
<td>• No financial documentation: According to Smedberg it was hard to say if Bollnäs municipality made financial profit from their service because of the complexity of calculation and comparison. This makes it difficult to show if the service had any financial savings.</td>
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<tr>
<td>• Aim reached: The projects helped the Bollnäs to move forward towards their environmental aim as well as an improved working environment. The positivity for the project has also made Bollnäs extend the amount of leased lighting each year since 2018.</td>
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<th>Opportunities:</th>
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<tr>
<td>• Impact: Bollnäs municipality got the opportunity to connect and share information for Tierp municipality with their procurement for the lighting service. This showed Bollnäs power to impact the service expansion and further establishment.</td>
<td>• Engagement: Bollnäs municipality has a limited amount of adjustment each year whereby Brighteco needs to carry out interviews to evaluate the new lighting in the space. Extra engagement is needed for these refurbishments, work and interviews to take place.</td>
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### 5.3.3 Similarities and differences

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<th>Similarities:</th>
<th>Differences:</th>
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<td>• Drive and demand: In both of the projects there was a drive and demand from the client's side that made the project possible.</td>
<td>• Financial savings: There was a clear statement about financial savings from NUS, meanwhile Bollnäs municipality didn’t have 100% valid information.</td>
</tr>
<tr>
<td>• Aim reached: The projects had a positive process that made both the clients in some way reach their environmental aims, whereby NUS could do further sustainable investments thanks to financial savings and Bollnäs municipality chose to extend the lighting service.</td>
<td>• Request: There was a documented difficulty for NUS to find a company who wanted to pursue their request of lighting as a service meanwhile there was no such information about Bollnäs. The 6 years gap and establishment between the projects could be a reason for this.</td>
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<td>• Importance of communication: In both cases there was an importance and success of clear communication and engagement.</td>
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<th>Similarities to clothing retail spaces:</th>
<th>Differences to clothing retail spaces:</th>
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<tr>
<td>• Novelty: Both of the cases are examples of lighting as a service in a new field which is the case in terms of clothing retail spaces since no documented case in that context was found in relation to this thesis.</td>
<td>• Activity: The activity of operation and refurbishment in both of the case studies differs in comparison to clothing retail spaces where the pace is high to promote new products and concepts.</td>
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<td>• Common needs: Most of the findings don’t apply to visual aesthetics and functions in terms of lighting but manifest a need for flexibility and adjustable lighting in order to support activity, service, low energy consumption (such as lighting control systems) which is also applicable to lighting in retail spaces.</td>
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6. Result

To implement lighting as a service to clothing retail spaces requires multiple factors and has multiple impacts. Many of them aren’t visual but referring to this thesis analysis and conversation with Kristian Renström, properly oriented luminaires can impact the visual appearance of the space (Kristian Renström, 2022 a). This thesis focuses on visual aesthetics and functional factors.

![Chart of lighting as a service impact to clothing retail.](image)

**Fig. 20** Chart of lighting as a service impact to clothing retail.

6.1 Flexibility and adjustable lighting design

Flexible and adjustable lighting are two visual aesthetic and functional factors that can initiate principles used in lighting as a service and cohere with retail lighting aims and strategies based on this thesis background research and analysis. See how this thesis result is evaluated in the mind map below:

![Diagram showing lighting as a service impact to clothing retail.](image)
The role of retail lighting requires flexibility and adjustability to allow fast and frequent refurbishment to promote new products and concepts to contain the novelty (EEF, 2009). Lighting as a service needs flexibility and adjustability to provide the best suitable service for the space and perform upgrades and maintenance. Flexible and adjustable lighting can be approached through following:

- **Lighting control system**: Luminaires compatible with a lighting control system can be installed wirelessly and be controlled through an app or control panel by the client. Allowing adjustable and dynamic lighting scenarios that can be changed in color, temperature and intensity which can be useful to for example enhance a new concept. Lighting control is both an aesthetic and functional method suitable for lighting as a service since it allows flexibility and control over many aspects (CIBSE, 2021). As an example, lighting control sensors decreased NUS’ energy consumption in 2014 in their project with Signify referring to this thesis case study. In a future perspective, lighting control systems could also provide the possibility of atmosphere changes when a business in premise shifts (CIBSE, 2021). Allowing
adjustments for the same lighting to suit a kids fashion store one day and a sports store another.

- Light integrated furniture: Creating an aesthetic, functional and flexible lighting solution by allowing lighting to move together with the interior during stores' fast pace of regular refurbishment without the need of reinstalling new lighting each time. Light integrated furniture should be demountable to facilitate lighting as a service in case of maintenance and upgrades. In relation to lighting control, the visual aesthetic possibilities are endless.

### 6.2 3d model

The aim of the 3d model is to visually demonstrate what lighting as a service in a clothing retail store could look like in line with the store’s business and concept. To demonstrate the findings of flexibility and adjustability, 3 versions of a 3d model in a general space were made for this thesis using the software program DIALux evo. The criterias for these 3d models is:

- Promote and support the store's visual aesthetic concept and functions by using the two aforementioned factors to demonstrate lighting control’s possibility of flexible transformation and aesthetics of light integrated furniture.
- Follow functional lighting as a service principles, meaning that lighting should be planned to be easily accessible for maintenance, upgrades and contain a low number of luminaires for maximizing to lower energy consumption.

Functional lighting solutions and qualities are also evaluated based on the previously mentioned study as guide, made by Ejhed, Greule, Felsch and Zumtobel (Jan Ejhed, Roland Greule, Markus Felsch, 2012).

Note that the 3d models have the same interior design and lighting layout but vary in terms of CCT, colored lighting, decorative lighting and materials in the interior to suit the vision of the store’s business. This to demonstrate the flexible and adjustable transformation of lighting control systems and its impact on visual aesthetics and functions.
Fig. 22 Plan of the 3d model and lighting typology.

Lighting layout and typology is based on a store's functional and aesthetical needs such as products representation and spatial recognition, based on key factors from previous research (Pia Markkanen, 2013). A recommendation from Kristian Rehnström stating that it should never be more than 2m between two tracks if the height of the ceiling is 3,3m, which is the case (Kristian Rehnström, 2022 b).

The 3d model has a mix of adjustable spotlights on a track with narrow (15°) and wide distribution (35°) for accent lighting and is planned keeping lighting as a service principles in mind by optimizing light distribution to lower the numbers of luminaires and energy consumption. In some areas a wider spotlight can replace two narrow. Linear LEDs are mounted in ceilings of shelves to highlight displayed products and also behind interior for vertical luminance to provide flexibility in cases of refurbishment.

Furnituring layout is inspired by previous site-visits and is planned to maximize displayed products by utilizing wall surfaces and minding placement of landmarks visible such as mannequins and posters. It also takes into consideration that a person in a wheelchair can pass between furnituring without problem. Furniture should also be modular and demountable to access integrated lighting.
Model A: Outdoor themed. Warm lighting temperature gives the impression of familiarity and a sense of safety. Vertical luminance behind shelves provides a sense of spatial recognition. Landmarks in the form of posters are highlighted with spotlights to create focus points (Jan Ejhed, Roland Greule, Markus Felsch, 2012) (for concept development - see appendix A).
Fig. 27 Model B/View A.  
Fig. 28 Model B/View B.  
Fig. 29 Model B/View C.  
Fig. 30 Model A/View D.  

Model B: Sport themed. Cool temperature lighting provides a sense of spaciousness (Jan Ejhed, Roland Greule, Markus Felsch, 2012), it also represents an energetic atmosphere in relation to sport activities. Orange decorative lighting is following the concept of the orange accent color (for concept development - see appendix B).
Fig. 31 Model C/View A.  

Fig. 32 Model C/View B.

Fig. 33 Model C/View C.  

Fig. 34 Model C/View D.

Model C: Fashion themed. The lighting temperature is on the warmer side to give a sense of safety. Blue colored lighting behind shelves cohere interior details as well provides a sense of spatial recognition (Jan Ejhed, Roland Greule, Markus Felsch, 2012) (for concept development - see appendix C).
6.3 Energy consumption

**Fig. 35** Lux levels on surfaces in outdoor themed 3d model. There were clear advantages of energy savings in the case of Signify and NUS thanks to only using light where it’s needed and lighting control. In relation to the case study’s method, the 3d model is following the suggestion from the study made by Ejhed, Greule, Felsch and Zumtobel, to be high in contrast for clearer perception and increased attention rather than high in brightness to lower energy consumption (Jan Ejhed, Roland Greule, Markus Felsch, 2012), but still consider lighting recommendations in general areas (minimum 300lx, maximum 750lx) (Ljuskultur, 2022). The software program DIALux evo calculated an energy consumption of a total 8.41W/m² for this space. The European and Swedish standard SS-EN 12464-1:2021 recommend 7-9W/m² for installed effect for lighting in retail (Ljuskultur, 2022).
7. Discussion

The aim for this thesis was to investigate whenever lighting as a service could be applied to clothing retail spaces and how it affects visual aesthetics and functions, if it could cohere with lighting design aims and strategies and what environmental advantages there are in the practice. The two case studies in this thesis present the practicality of lighting as service and improved visibility for working environments in schools and offices. What differs from retail spaces is the necessary needs for visual aesthetics and frequent updates. A middleground is needed for the two to cohere since neither the practicality of lighting as a service or visual aesthetics and functions in retail spaces can be disregarded. Based on this thesis result, flexible and adjustable lighting solutions are a common need that cohere lighting as a service and clothing retail spaces due to the fast and frequent refurbishment to contain novelty in stores and to support activity, low energy consumption and service of maintenance and upgrades. The thesis could present two visual aesthetic and functional factors that are also flexible and adjustable: lighting control system and light integrated furniture.

The concept of lighting as a service is to provide energy efficient lighting, maintenance and upgrades according to the client's needs (Philips lighting, no date). The 3d model is demonstrating the solutions of lighting control systems and light integrated furniture which is following actual needs of the space and service and avoiding general lighting solutions that often doesn’t correspond to the main function of the space, such as lighting in a grid-based systems that is often installed before occupation and still used in many commercial spaces today (Claudia Dutson, 2010). Grid-based lighting has also shown to be accountable for nearly 20% of the total energy production worldwide (Yao-Jung Wen, Alice M. Agogino, 2010), as earlier presented in this thesis. The homogenous lighting effect that’s usually created by grid-systems doesn’t cohere to recommendations of retail lighting design in terms of creating contrast and letting products stand out from its surrounding, referring to earlier presented litteratur by Pia Markkanen (Pia Markkanen, 2013) and Ejhed, Greule, Felsch and Zumtobel (Jan Ejhed, Roland Greule, Markus Felsch, 2012). According to aforementioned literature, the purpose of retail lighting design is simply explained to attractively present products and visual stimuli. When observing stores in Stockholm city it became clear of what provided stimuli and what didn’t. Glare and excessive bright scenarios interfered with the impression and focus of products. In relation to the 3d model, this resulted in a lighting layout where directions of lighting distributions are maximized while still considering lux levels to avoid exaggerating brightness. This managed to decrease energy consumption which is cohering with global sustainable goals by improving energy efficiency.

A downside to the result is the difficulty of compassion to earlier cases since there were no documented cases of lighting as a service in retail spaces in relation to this thesis. This made the 3d model compared to cases with different context, aims and activities compared to retail. A case where the 3d model was designed based on an actual brand, specific space and their needs would provide a
more contextualized result. As mentioned in limitations the outdoor brand Houdini was contacted for an interview in relation to this thesis but declined due to lack of time. The oblong and general space of the 3d model is certainly applicable to other spaces but is lacking in terms of connection to a brand’s philosophy, specific needs and aesthetics related to brand identity.

The two case studies in this thesis have shown that being a first case scenario of lighting as service in a field includes some uncertainty for the project's outcome and that the lack of establishment of the service is a barrier, meanwhile a decisive factor for lighting as a service projects according is client-demand and drive. Research in relation to this thesis has presented how lighting as a service is still a new concept and knowledge is limited in fields. Referring again to Roger Sexton’s statement: lack of awareness is the biggest obstacle, not only for lighting as a service, but generally to net-zero design within the built environment (Roger Sexton, 2022 b). There’s a need and responsibility as a service supplier and lighting designer to educate and develop practices to further share knowledge with others within and outside the industry to create client-demand, which is also a statement in the previously mentioned publication from CIBSE in 2021 (CIBSE, 2021). Referring to personal statement about circularity in the lighting industry in CIBSE publication made by Mark Ridler, Head of BDP Lighting and a non-executive Director of BDP London:

“"But even if we get it all right and specify lights made of mung beans that are powered by their own methane and grown on site, none of this will make a jot of difference if the rest of the construction industry (and clients) do not play the same game.” - Mark Ridler (CIBSE, 2021)

Lighting as a service can be further developed if considered earlier in the design stage in collaboration with others in the built environment. As well as lighting as a service can create challenges and frames it can also create new possibilities to design spaces with quality lighting affecting visual aesthetics, function and environmental factors such as presented in this thesis.

7.1 Conclusion

There’s an interest among fashion brands to aim for a more circular production model (Ellen Macarthur Foundation, no date) and if more clothing brands aim for a 100% circular ecosystem, like Swedish outdoor brand Houdini, there will most likely be an increased demand for circular principles including their stores. Since lighting as a service principles cohere with the circular economy model, the aim for this thesis was to investigate whenever lighting as a service could be applied to clothing retail spaces and how it affects visual aesthetics and functions, if it could cohere with lighting design aims and strategies and what environmental advantages there are in the practice.
The process of the thesis has shown through background research, case studies, swot-analysis and site-visits the complexity of relations of the possible application of lighting as a service to clothing retail spaces. Investigating retail lighting design strategies and aims opened up multiple factors that needed to be considered by how lighting qualities can affect the experience of the customer and products. Meanwhile investigating lighting as a service and documented case studies also had its conditions for successful service. A common basis and coherence was flexible and adjustable lighting since it could be connected to the pace of retail business models and lighting as a service activities. These findings were transformed into lighting design solutions considering visual aesthetics and functions: lighting control systems and light integrated furniture. Both of these factors were visually demonstrated through a 3d model to show what lighting as a service in a clothing retail store could look like. An enviromental advantages in lighting as a service is the principle of low energy consumption which affected the lighting layout and energy performance of the 3d model.
8. References


National union of students (NUS) (2022) *Who we are*. Available at: https://www.nusconnect.org.uk/nus-uk/who-we-are (Accessed: 4 April 2022).

Philips lighting (no date) *Circular lighting*. Available at: https://www.lighting.philips.com.eg/services/circular-lighting.


UN environmental program (2019) *UN Alliance For Sustainable Fashion addresses damage of ‘fast fashion’, UN environmental program.*

9. References - Figures

Fig. 1, 2  Circular economy and linear economy. Illustration by Elsa Frisén.

Fig. 3  Methodology chart. Illustration by Elsa Frisén.

Fig. 4  Sketch based on a portion of a plan of a mall in Stockholm. Illustration by Elsa Frisén.

Fig. 5 & 6  Store A/Fashion store in Stockholm city. Photo by Elsa Frisén.

Fig. 7, 8, 9, 10  Store B/Fashion store in Stockholm city. Photo by Elsa Frisén.

Fig. 11, 12  Store C/Sport store in Stockholm city. Photo by Elsa Frisén.

Fig. 13, 14  Store D/Outdoor store in Stockholm city. Photo by Elsa Frisén.

Fig. 15, 16, 17, 18  Store A, B, C, & D in black & white. Photo by Elsa Frisén.

Fig. 19  Premise in Bollnäs municipality. Photo by Brighteco.

Fig. 20  Chart of lighting as a service impact to clothing retail. Illustration by Elsa Frisén.

Fig. 21  Chart of the evaluation of the result. Illustration by Elsa Frisén.

Fig. 22  Plan of the 3d model and lighting typology. Drawing by Elsa Frisén.

Fig. 23, 24, 25, 26  Model A/3d model of an outdoor themed store. Image by Elsa Frisén.

Fig. 27, 28, 29, 30  Model B/3d model of a sports themed store. Image by Elsa Frisén.

Fig. 31, 32, 33, 34  Model C/3d model of a fashion themed store. Image by Elsa Frisén.

Fig. 35  Lux levels on surfaces in outdoor themed 3d model. Image by Elsa Frisén.
10. Appendix

**Appendix A:** Brainstorming of aesthetics of an outdoor retail concept. The concept is inspired by the site-visit of Store D/Outdoor store. A target group of various ages with an interest in outdoor activities and lifestyle. Neutral tones, plywood interior and warm lighting temperature to represent a low sun and the presence of nature. Landmarks in the form of posters are highlighted with spotlights and are meant to envision a scenario for the customer and enhance the outdoor concept of the store.

**Appendix B:** Brainstorming of aesthetics of a sport retail concept. The concept is inspired by the site-visit of Store C/Sport store. A target group of various ages with an interest in sport activities. A gray base color is applied to enhance a vivid orange accent color which could represent a brand identity.
Appendix C: Brainstorming of aesthetics of a teenage fashion retail concept. The concept is inspired by the site-visit of Store A and B/Fashion store. A target group focused on teenagers of all genders. Chipboard interiors represent a raw aesthetic. Decorative pendants over the counter provide a contemporary interior detail.