Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

Parisa Ebadat

Designing of Circular LED Downlights

Master's thesis in Industrial Design
Supervisor: Jon Herman Rismoen
June 2022

NTNU
Kunnskap for en bedre verden

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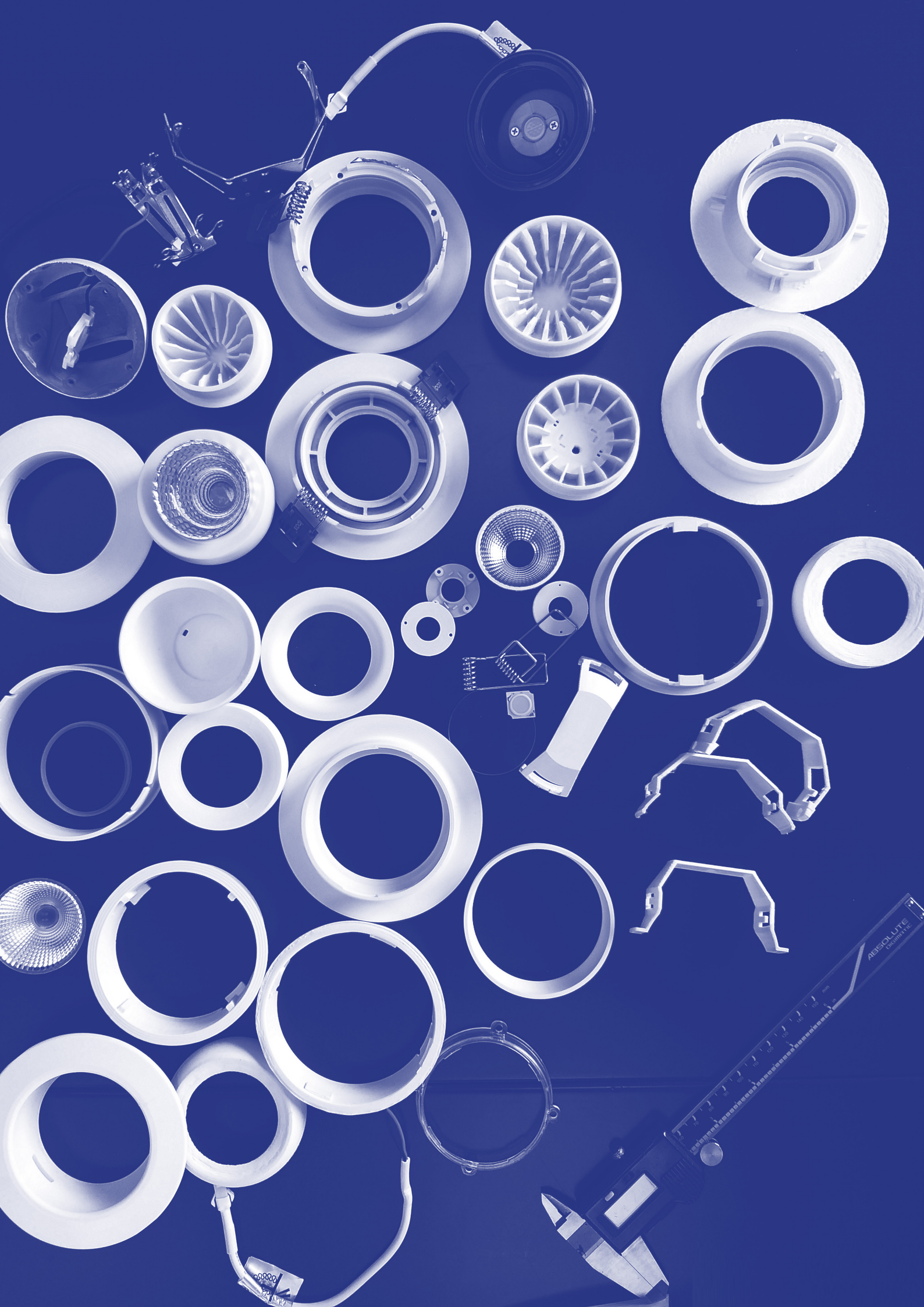
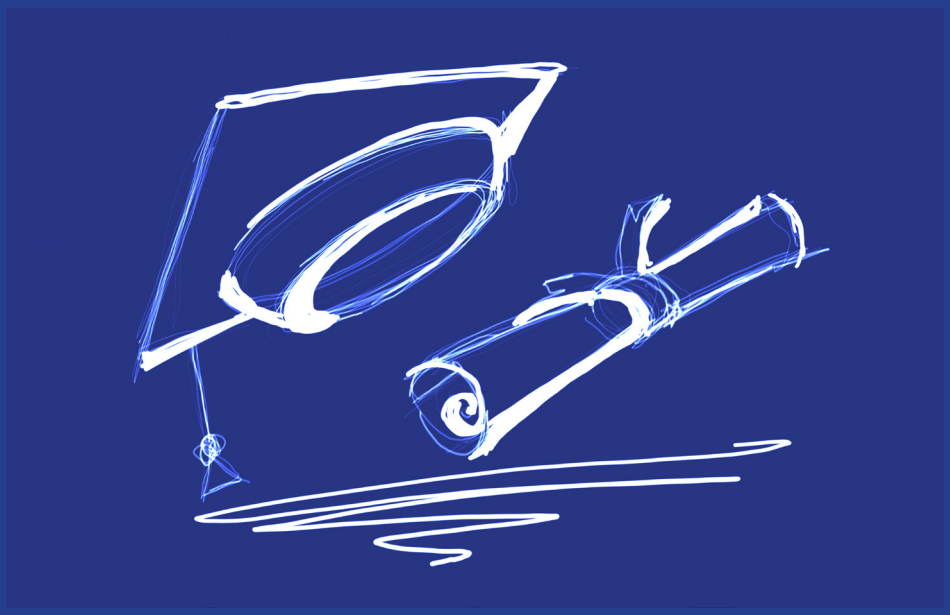


"Modern consumerism is a waste-making culture, in which objects, spaces and buildings are prematurely 'aged' and devalued, and then turned into waste, in order to make room for the new." (Crocker, 2017)



Acknowledgement

Initially, I would like to thank CTM Lyng and all the nice employees there for the support and guidance they gave me throughout the thesis. Thanks to Ståle Sund and Terje Lillemo, for their trust one my work and for the opportunity giving me to work on this project. Thanks to Ståle for all efforts he has done for my project. Thanks to Vidar Løw-Owesen and Frank Robert Husby in the Ipas department for their feedback on the product. Thanks to Katarzyna Faściszewska, the Industrial Designer at CTM Lyng, for her time and professional guidance during the design and prototyping phase.

I would thank the participants in the interviews, Nortek Elektro AS, for their time and interesting points of view. Thanks to the technical people in IV Group for injection moulding guidance and Leksvik Industrimekanikk, Helge Aanonli and Robert Tømmerdal for their help and advice on the metal manufacturing requirements.

I also want to thank my supervisor, Jon Herman Rismoen, for his insights, opinions and support during the project. Thanks to Tessa and Clayton who helped me with 3D printing when it was difficult for me to come to the campus.

Many thanks to Øyvind Ugendal, Stian Nilsen and Bjørn Damhaug who helped find out the possibilities of the master thesis nearby Åfjord, where I'm living. I also thank them for letting me sit in Coworkz during my project. Thanks to my kind friend Karoline Larsen in Åfjord Coworkz for her support and motivation gave me during the project.

Last but not least, I want to thank heartily to my husband who was with me in all the ups and downs, for his support and for giving me useful advice on the technical parts of my project. Thanks to my family in Iran who are always positive and encourage me to move forward in my career.


CTM
LYNG
mTouch
Dimmer
18
18
Termostat

My photo with the final concept for Eliaden Expo.

CTM Lyng’s office, Vanvikan, May 2022.

Abstract

Background

Our generation is experiencing a higher level of production and consumption, greater than ever, and now the time is to face these issues and step up efforts to develop more sustainable patterns.

According to the United Nations Organisation (UN), 17 main goals are presented to save our planet. One of these goals is to find lasting solutions in economics and the environment through innovation and technological progress. It is also considered in the goal target No.12.5 that by 2030, we should substantially reduce waste generation through prevention, reduction, recycling and reusing. (UN, 2019) This motivation pushes me forward to dedicate this master's thesis to the circular design approach and be involved in my duty as a responsible designer.

Goal

The primary purpose of this thesis is to discover appropriate solutions for designing and producing the Light-Emitting Diode (LED) downlights which will last for a longer time and have more closing loops in production and consumption. LED downlights, in most cases are designed and produced with a slight difference in appearance, out of virgin materials (mostly aluminium), placed inside the ceiling or walls (that are basically invisible) and usually end up in the waste after the lifespan.

Methode

I have considered the 4D design process and defined the specific tasks that would be beneficial alongside the project. Because of my educational plan and the thesis schedule, I had to finish the project in 4 months instead of 5. This leads to holding the tasks in parallel. The ideation, for instance, has been started very early to make much room for the Development and Delivery phase.

Result

The final result of the thesis is a series of LED downlights, available in two types; adjustable and fixed, that respond to the requirements of the circular economy. The product has been designed in response to findings and experiments during the project, which have been described further in the thesis. This was my great honour that CTM Lyng presented my concept for the first time at the Eliaden exhibition, Lillestrøm in June 2022.

Sammendrag

Bakgrunn

Vår generasjon opplever et høyere nivå av produksjon og forbruk, større enn noen gang, og nå er tiden inne for å møte disse problemene og øke innsatsen for å utvikle mer bærekraftige mønstre.

I følge FNs organisasjon (FN) presenteres 17 bærekraftmål for å redde planeten vår. Et av disse målene er å finne varige løsninger innen økonomi og miljø gjennom innovasjon og teknologisk fremgang. Det er også vurdert i mål nr. 12.5 at vi innen 2030 skal redusere avfallsproduksjonen betydelig gjennom forebygging, reduksjon, resirkulering og gjenbruk. (FN, 2019) Denne motivasjonen presser meg til å dedikere denne masteroppgaven til den sirkulære designtilnærmingen og involverer meg som ansvarlig designer.

Mål

Hovedformålet med denne oppgaven er å finne passende løsninger for å designe og produsere Light-Emitting Diode (LED) downlights som vil vare i lengre tid og ha mer lukket sløyfe i produksjon og forbruk. LED-downlights er i de fleste tilfeller designet og produsert med en liten forskjell i utseende, av jomfruelige materialer (for det meste aluminium), plassert inne i taket eller vegger (som i utgangspunktet er usynlige) og havner vanligvis i avfallet etter utløpt levertid.

Methode

Jeg har vurdert 4D-designprosessen og definert de spesifikke oppgavene som ville være fordelaktige ved siden av prosjektet. På grunn av min utdanningsplan og oppgaveplanen måtte jeg fullføre prosjektet på 4 måneder i stedet for 5. Dette fører til at oppgavene er gjort parallelt. Idéfasen er for eksempel startet veldig tidlig for å gi mye plass til utviklings- og dokumentasjonsfasen.

Resultat

Sluttresultatet av oppgaven er en serie av LED-downlight, tilgjengelig i to typer; justerbare og faste, som svarer til kravene til den sirkulære økonomien. Produktet er designet som svar på funn og eksperimenter underveis i prosjektet, som er beskrevet videre i oppgaven. Det var en store ære for meg at CTM Lyng presenterte konseptet mitt for første gang på Eliaden-messen, Lillestrøm i juni 2022.

NTNU
Fakultet for arkitektur og design
Institutt for design

Vår dato Vår referanse

Deres dato Deres referanse

Master's thesis for Parisa Ebadat

Designing a series of LED lights with a focus on sustainability.

As products' life cycles get shorter and people get more used to buying products use them for a while and throwing them away, the circular economy and sustainable approaches have drawn more attention among some governments and producers. It is therefore important to know how a designer contributes to this phenomenon. How much effort must a designer put into designing long-lasting products or products that are easy to recycle? This master thesis will focus on the influential factors such as functionality, easy to take apart and repairable products to make the lifetime of a series of LED lights longer than it has been so far and to come up with an appropriate design solution. This criterion is in contrast with the way most of the products are designed and produced in recent years. The project will be in collaboration with CTM Lyng company, a Norwegian company aiming to produce downlights with recycled materials.

The master thesis will include:

- Analysis of the LED lights' life cycle.
- Research for long-lasting solutions such as easy to repair, recyclable and easy to recycle materials.
- Interview with the recycling company.
- Important features and standards of the lightings.
- Designing, modelling and testing an appropriate product by using theoretical and influential aspects.

During the process, fewer concerns will be allocated to the final product price and production costs.

Responsible tutor: Jon Herman Rismoen
Business contact:

Start date: 07-01-2022
Due date: 07-06-2022

Trondheim, NTNU, dato
07.01.2022

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List of Abbreviations

AC: Alternating Current

CE: Circular Economy

DRS: Deposit Return Scheme

EoL: End of Life

IP Code: Ingress Protection Code

K: Kelvin

Kr: Norwegian Kroner

LCA: Life Cycle Assessment

LED: Light-Emitting Diode

PA: Polyamide

PC: Polycarbonates

PCB: Printed Circuit Board

PP: Polypropylene

PPS: Polypropylene Sulfide

UN: United Nations

W/mK: Watt per meter-kelvin

W: Watt

Table of Contents

Introduction

Beginning

Different advertisements, publications, NGOs and global organizations, all are showing me the same trend in the design world; it is more than ever crucial to saving the planet! As a responsible designer, I don't underestimate my slight contribution to this phenomenon and should think about the consequences of my decisions. These thoughts, which have shaped my mindset for years, were integrated with my strong desire for product design and made me determined to discover a company in which I could fulfil all these dreams.

During the first online meeting that I had with CTM Lyng AS, we discussed the overall framework of the circular downlight and I figured out the opportunities for the project. Although designing a downlight may seem a simple task, the project got more complicated and broad as it goes by. One of the main challenges was considering various factors and product boundaries while tackling the limitations and regulations.

There were many unanswered questions concerning this project since it was a new kind of downlight with some initial goals such as being repairable, from recycled material and having the closing loops in production. It was important to achieve all the resources and find the best response to existing concerns. The material for the product was not defined completely and I didn't know the specifications of each part. I used my research and experiment to find the best solution for each task and yet it needs a lot to redesign when it comes to mass production.

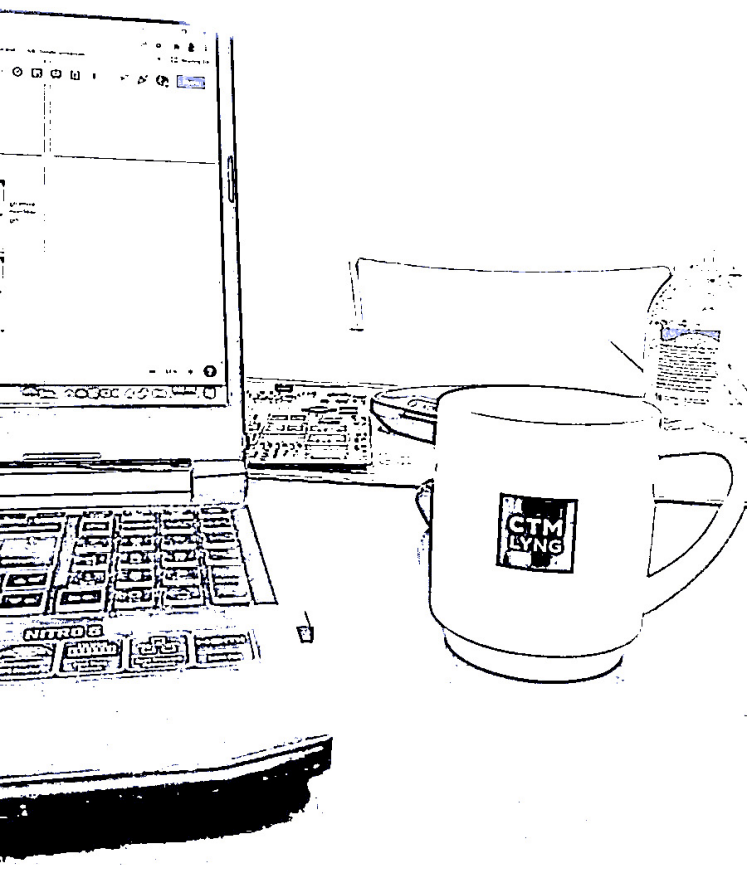
Collaboration with CTM Lyng

CTM LYNG AS is a Norwegian leading manufacturer and supplier of home security products, Welfare Technology, Energy Economy, as well as lighting and heat management, for all types of buildings, known under the brands mKomfy®, Aqua Xpress®, Microsafe®, Centrol® and mTouch Home®. CTM Lyng is a business to business company. It means the clients are not the retailers, they are the professional market such as electrical companies known as wholesalers. For the years, CTM Lyng has had ethical guidelines regarding fewer footprints to have a more sustainable future. 'Store sko, Små fotavtrykk' is their motto translated as 'big shoes, small footprints'. (CTM Lyng ethical guidelines) The company has recently decided to extend new horizons by considering a circular economy pathway.

According to their new application, CTM Lyng got the patent and investigations for designing and manufacturing the products under the brand named CircuLine™. It means producing products from recycled materials that can be recycled again in the circular economy cycle (CTM Lyng press release, 2021). The first task has been started with designing the circular LED downlight. The ambition is to implement the achievements such as decisions and design guidelines of this project to the other company's products in the future.

During the project, I sat in the company's office in Vanvikan two days a week and benefited from the great atmosphere and professional consultation there. Collaborating with the company brought me a lot of experience and opened my eyes more to the responsibilities I have as a designer. I was in contact with the project manager, company manager, industrial designer and development team. It was a good experience to have feedback from different perspectives, join related meetings, find out the necessary information through contacting people and be linked to other professions. I got the chance of being in the Klæbu office several times as well as visiting the IV group, Leksvik for the injection moulding process. It was also a great opportunity to visit the process of manufacturing the electrical components in person at the production site in Vanvikan.

Apart from the professional experience that I've gained, I've been impressed by the friendly atmosphere in the company. They all were welcoming whenever I needed help and they put a lot of time and effort into this master thesis. I've learned a lot from them and appreciate the way they support new thoughts and potential.



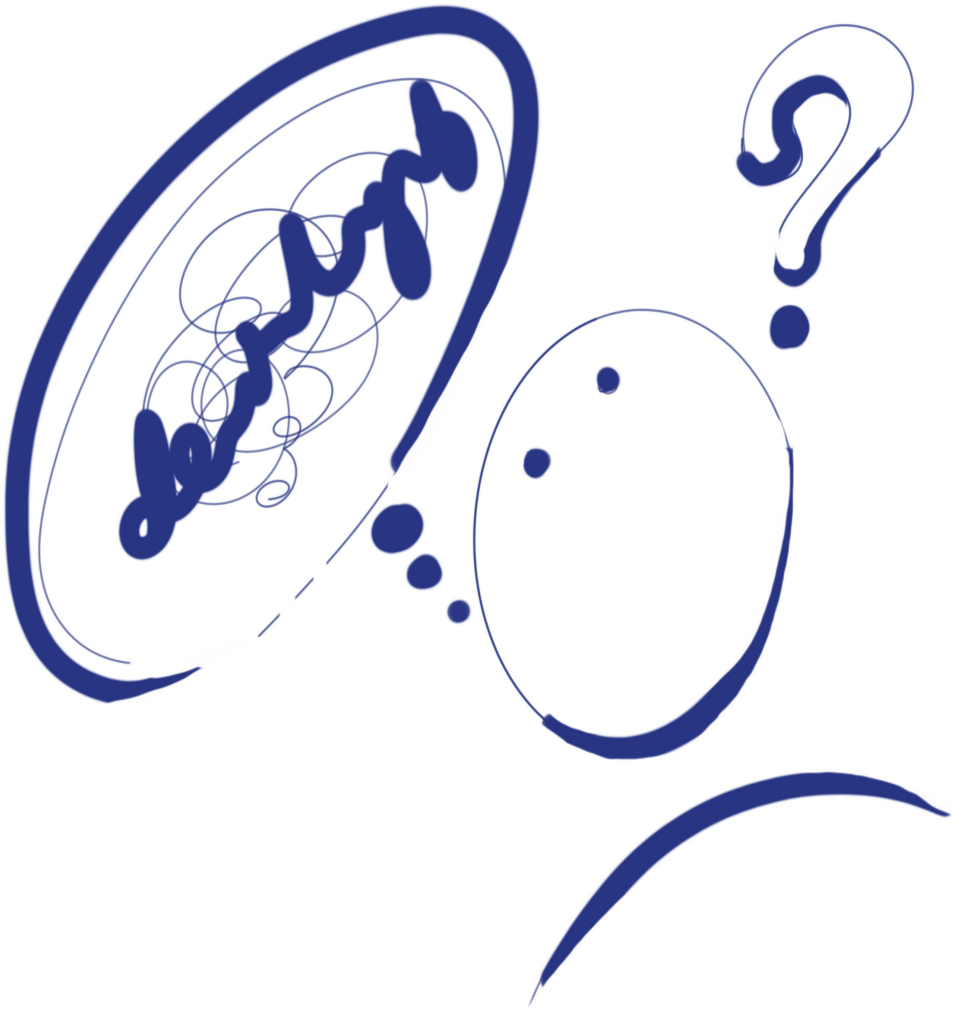
Task Description

Literally, most products in the electrical and lighting industry are designed and manufactured to be thrown away after the products' lifespan. In this project, CTM LYNG and I aimed to tackle this issue.

The first notion was to design and produce products out of recycled materials. This considerable challenge demanded research and experiments by experts to find an appropriate material that suits product requirements such as safety and standards. The new materials would have specific properties which influence design decisions.

The next step was to contribute to extending the products' lifespan through innovative product design solutions. The solutions could be divided into different categories.
A. Technical decisions that lead to a longer lifespan. Being aware of the features of LEDs for instance makes this point obvious that we need an appropriate heat sink to transfer the heat away from the component. However, we can't underestimate the quality of the components themselves. B. Designing an easy to repair and refurbish product in which the parts can remain in the usage cycle. C. Consider how these products will be ended after their lifespan. An option is to keep different types of recyclable materials separate to have simpler and reasonable recycling processes.

It is also important that the company consider the strategic side of the product and prepare the required platform, find partners and consider the future of the product. What would happen after the product is launched in the market? Who is responsible for repairing it? How it all would happen? The strategic side of the project is as important as the product itself, but in this thesis, the main concentration is on product design.



Process and Methods

Design Process: The design process that I chose is based on the 4D process, discovering, defining, developing and delivering. Each area has its tools and methods to catch the final purpose. I have selected this design method since it was a flexible one and suits my project well. Another reason for this process was that I could do some parts in parallel and be more effective according to the tight schedule.

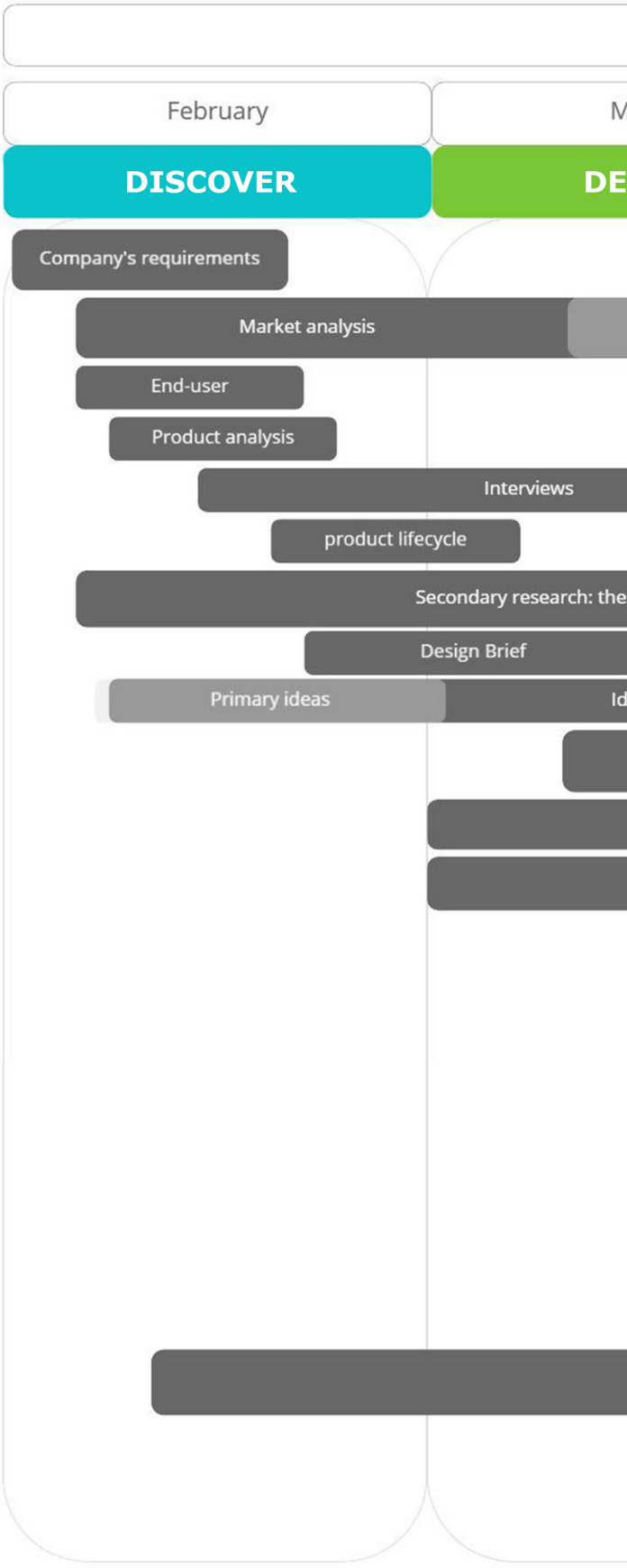
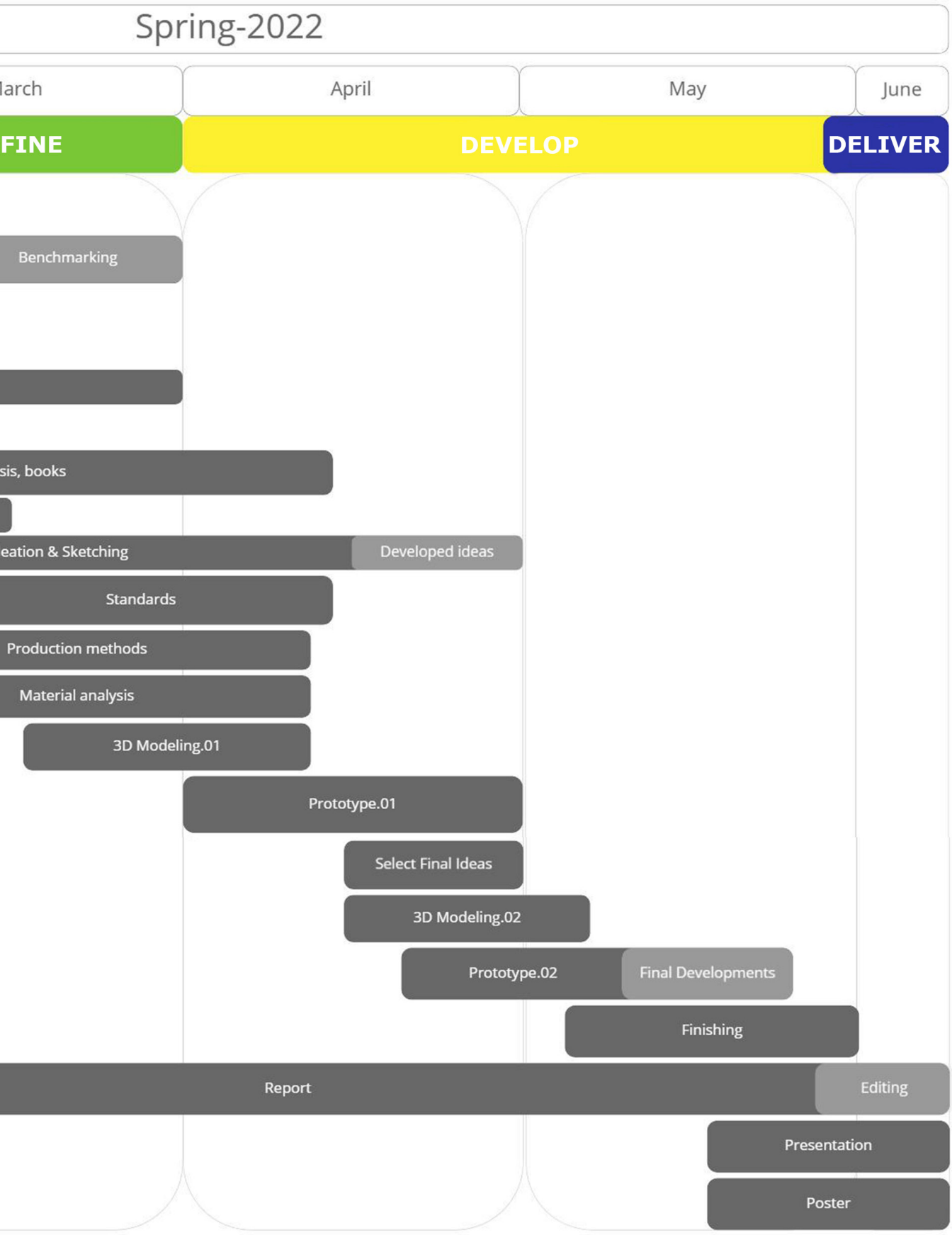


Figure 01. Design process.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Production methods
Material analysis
3D Modeling.01
Prototype.01
Select Final Ideas
3D Modeling.02
Prototype.02
Final Developments
Finishing
Report
Editing
Presentation
Poster

Project milestones: I first made the project milestone upon the important deadlines that I knew at the moment. The other important arrangements have been added by the exact dates. It includes meetings, presentations and other works. The milestones make the arrangements clear for the company, my supervisor and myself.

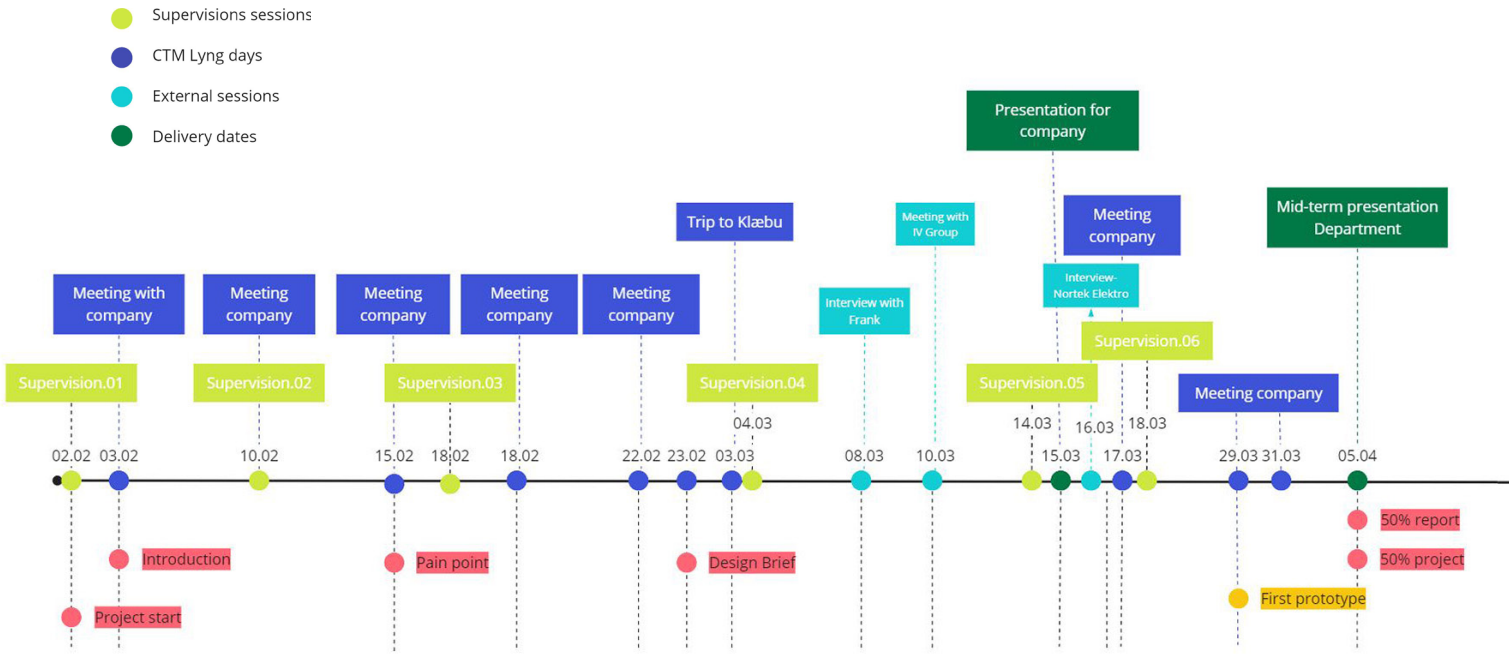
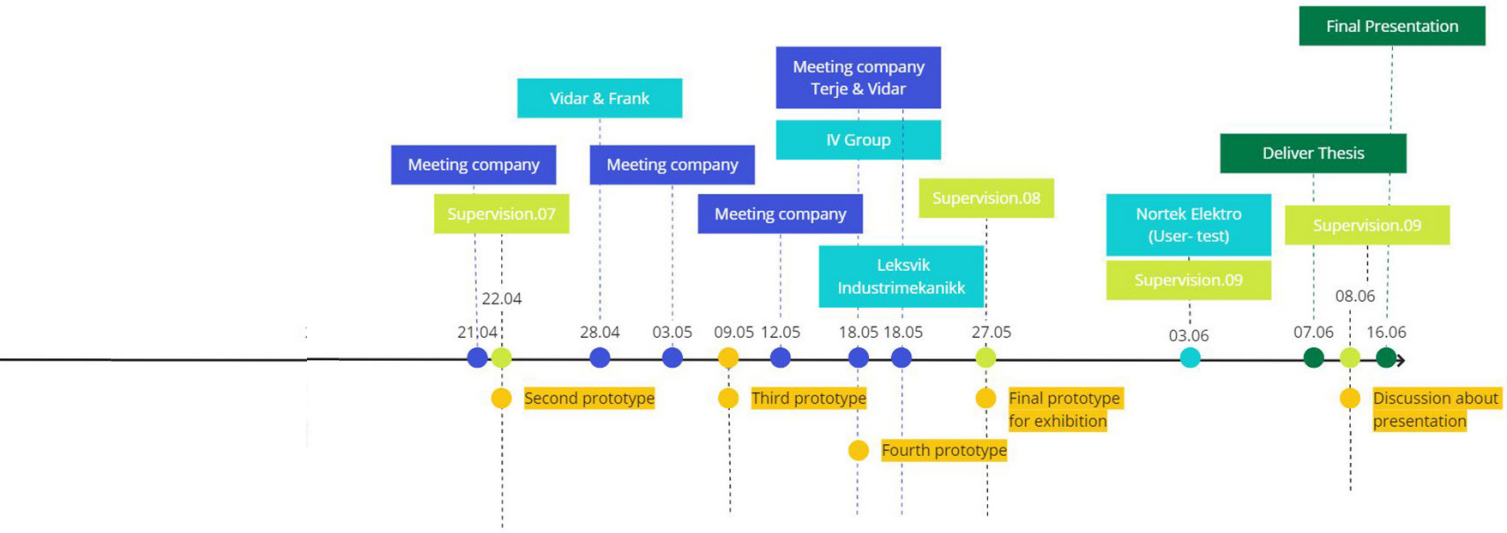


Figure 02. Milestone chart.



Miroboard: From the early stage of the project, I made a specific board in Miroboard to picture every task I was supposed to do. This board developed more and more as the project went forward and led to a beneficial board that visualised data for not only me but also for the company and my supervisor.

One Drive: At beginning of the project, Ståle (the company's manager) made a folder in one drive and shared with me the important files for the project. It was an excellent communicating platform between the company and me to share useful and important information.

Google Drive: I've made a 'Master Thesis' folder for the notes, thesis textbook draft and photos. Google Drive was the easiest way to have all of the needed information in one place and also made it possible for me to share the texts with my supervisor.

Discover

This phase, the project's initial step, consists of a combination of theoretical studies and practical activities that I've obtained regarding the essential information for the project's outset. There aren't many scientific viewpoints in this thesis since there was not enough room to focus on the theories. Most considerable insights were reached from interviews, and others were extracted from literature reviews, books and related master thesis.

Company’s Requirements

There were some initial requirements at the beginning of the project that make the basis of this master thesis. I’ve achieved these dos and don’ts during different meetings with the company, it then became more completed and detailed during project developments. All of these factors have been noted on my Miroboard as sticky notes to remember and review alongside the project.

Figure 03. Sticky notes from the meetings with CTM Lyng.

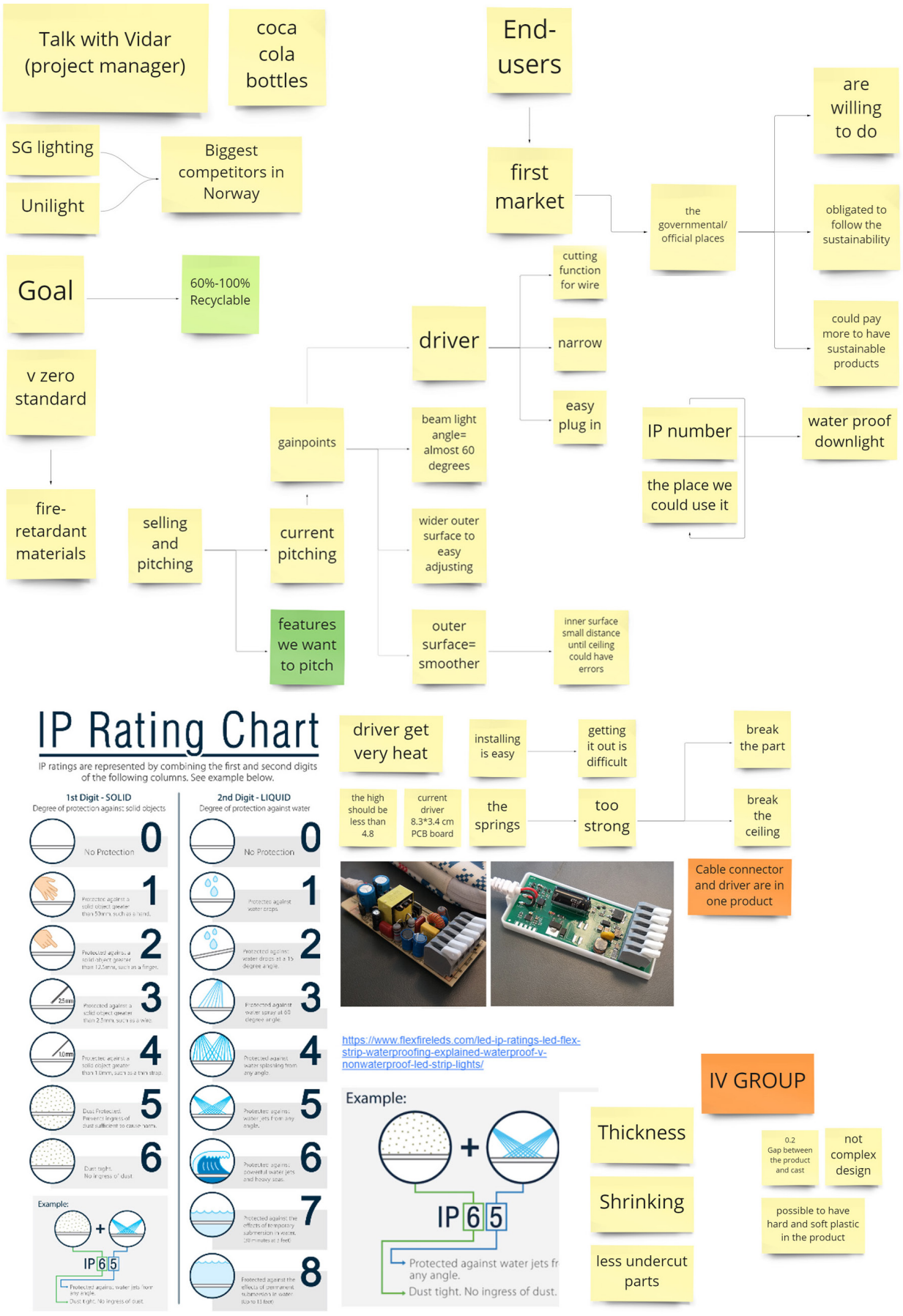


Figure 04. Sticky notes from the meetings with CTM Lyng.

Circular Economy

Although the project borders required more practical tasks, several literature reviews have been done as a back and forth process between design stages to get an overall understanding of the attitude and define the focus area. The theoretical research led to influential facts regarding the circular economy. There was not enough space to jump deeply into the history and origins of the circular economy, therefore more attention was concerning the practical information and guidelines of this approach. This was the stage that CTM Lyng was aiming for from the beginning of the project. So I found this notion crucial to review and structure my mind before the project proceeds. The achievements have been collected through the related books and previous master thesis at NTNU.

Traditionally circular economy used to be known as the linear lifecycle based on a constant sequence of production and consumption (Chpman, 2017).s It then turned into a circular cycle of how the end of life in a certain product can lead to the creation of a new one. This linear approach has been existing since the 1970s but the significant attention drawn by industries and consumers didn't take place up until recent years (Preston, 2012). Moreover, several documents proved that the exact origins of the Circular Economy (CE) cannot be traced back to a single date or author. (Madeleine Kristin Wieser, 2021,p22) It is nevertheless important that the European Commission adopted its first circular economy action plan back in 2015. (Sillanpää & Ncibi, 2019)

According to the conference series of 'Earth and Environmental Science,' LED lighting products have a significant environmental impact in a variety of categories, including primary energy, toxicological effects, global warming, the level of environmental acidification, and so on. All of these influences might lead to more efficient goods by improving the product design process (using ecodesign). The producer of lighting supplies should address circular economy factors at the End of Life stage (EoL) such as repair, reuse, remanufacturing, retrofitting, recycling, and upcycling in the initial design stage, not just energy savings from the usage stage or raw material selection. (Grigoropoulos, 2021)

As a literature review on the circular economy, I've read through Madeleine Kristin Weiser's master thesis. The thesis focused on the circular economy of plastic furniture. I found it useful to go through the 12 circular design guides for use of plastic in furniture that the author has presented (Kristin Weiser, 2021). Each of these guides described in detail has influenced my mindset about my project. Here I've just presented the name of these twelve guidelines and skipped the descriptions.

1. Design service and system.
2. Design with respect for the material.
3. Design out of waste.
4. Design to close the loop.
5. Design for recycling system.
6. Design for recyclability
7. Design with recycled plastic
8. Design for resilience
9. Design for versatility
10. Design for emotional attachment
11. Design for multiple use cycles.
12. Design for dis- and reassembly

CTM LYNG,
From linear to circular economy

Today in the CTM Lyng, the production and marketing are based almost on a linear base. The company, however, has begun to change this basis and develop the products toward a circular lifecycle. The illustrations show the current lifecycle of products in the company and the future plan.

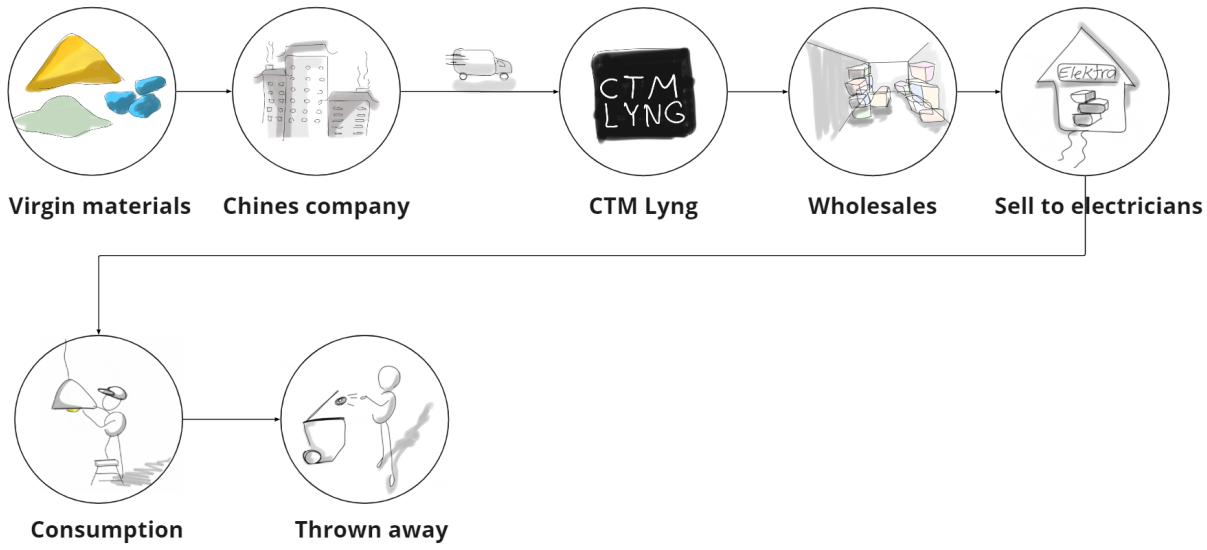


Figure 05. Linear economy of CTM Lyng, today.

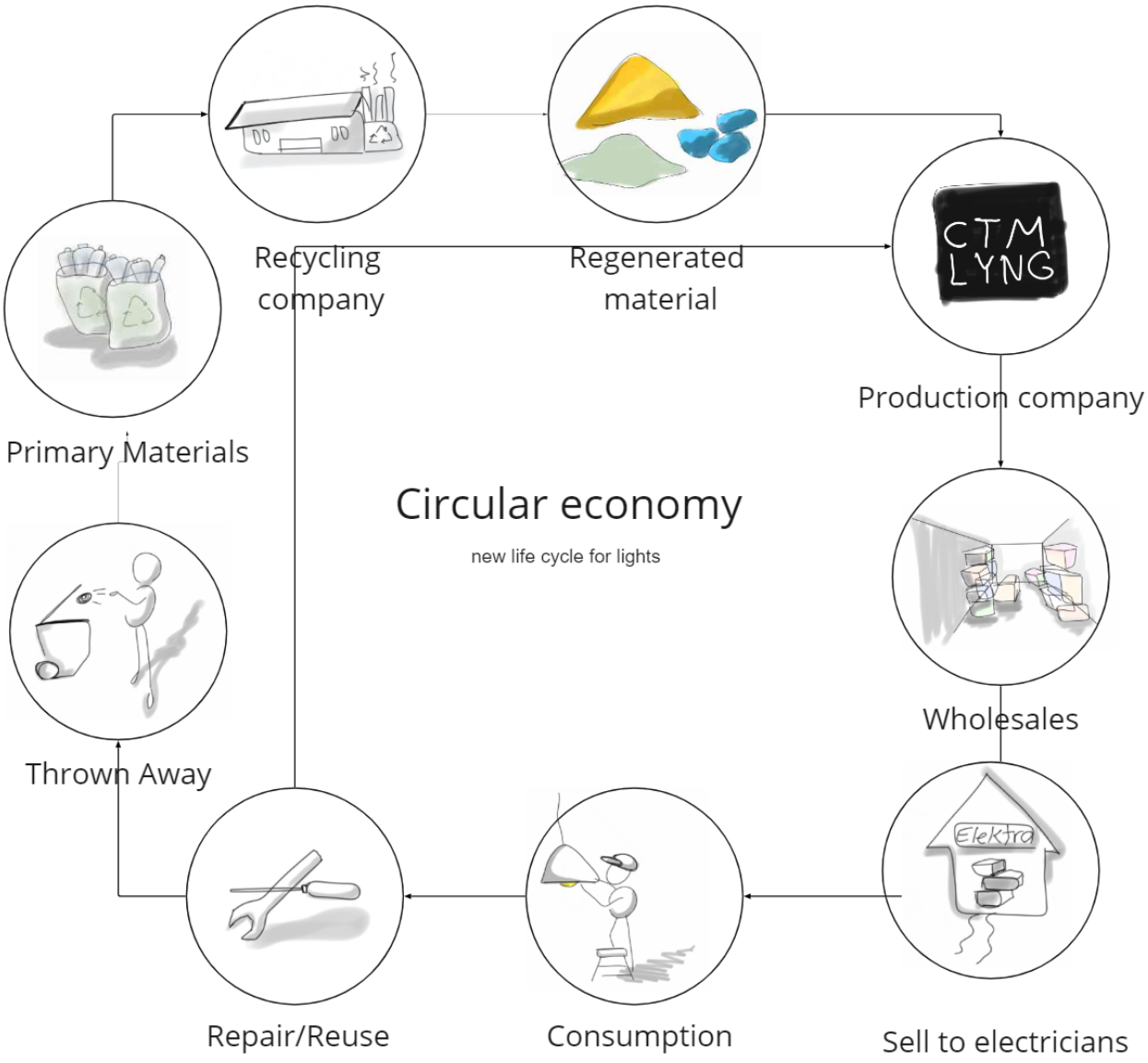


Figure 06. Circular economy of CTM Lyng, future.

The Value of Refurbishment

When it comes to a sustainable and circular approach, it is not only important to consider the current solutions like using recycled materials, but also the designer and the manufacturer should take into consideration how the product parts could be reused. Following this, refurbishment is an important fact to be considered for a circular economy. To keep the product more in the using cycle, It is important to refurbish the product and make customers willing to do so instead of purchasing something new. (Champman,2017,p 386) Therefore apart from the easy dis-assembly features, I had thought about which features of the lighting would make positive responses from the users to refurbish the product after its first life.

Imagine we are in 2032, ten years after the circular downlight has been produced and launched. Which problems are there with this product now? Have the colours lost their quality? Do the parts need to be repainted? Maybe painting is not possible and the part has to be replaced? All these questions have to be answered either by design or the company's strategic plan. On one side, the designer can improve the product's strengths and make it easy to refurbish and on the other hand, the company's sustainable strategy should support this scenario by keeping it cheaper and more reasonable to paint the product or replace the certain part. If the designer and the company fail to reach this goal the customers rather throw the product away for purchasing a new one. What happens if the customer throws the product away? In this case, the product is still useable and can have a second life but need to be returned to the company instead of the trash basket.

Besides the financial value of the refurbished products, it is important to know what other values this refurbished product brings to the customers. People consider refurbished products as second hand and this fact most of the time decreases the value of the product. It is, therefore, important to think about how we could add value to the second lifecycle of the product and make it more desirable to use. (Champman,2017) As it is mentioned earlier, downlights are not decorative products, their functionality always overtakes aesthetics. Costumers expect a downlight to work appropriately, if they believe that a second-hand downlight is as effective as the new one the value has been achieved.

Champman has presented Van Weelden's attitude towards the importance of increasing the acceptance of refurbished products by the customers. Following this notion, he has suggested several design strategies to turn the negative sides of the refurbished products into positive ones. (Champman,2017)

- Highlight the environmental benefit of refurbished products for example, by atheistic or by packaging.
- Turn the negative connotation of the first user into a positive one for example, through storytelling and memories.
- Discover the vulnerable parts of the product (the parts that are most likely to show signs of wear and tear) and try to take into consideration of it in the design process.

Future of Downlight

Looking at the downlights history, it can be realised that the aesthetics of this product was stable and without considerable changes during years. In contrast with the other products, few people are looking for a specific downlight with a unique appearance! So in the online market review of the similar product phase, I found it difficult to gather downlights which are distinct in forms and appearances.

The most important features are functionality and durability. During the process, I've thought about what makes a LED downlight durable and how can I design it to be used for many years. One critical point is to have a structure with enough strength for further developments, simple and straightforward to replace the parts. Then, I can add a value more than the existing functional features. It means the structure of the product could be used for future downlights despite the growth in production methods and technology.

One example could be the smart downlights today that make it possible for the user to sync the lights by the mobile app and control them remotely. Years ago, when the electric companies were producing downlights, they were not aware of this development in products. By the way, these anticipations, are not easy to achieve and demand much more research. For this reason, I just suffice to these possibilities in theory and didn't set the goal of my product as a futuristic design. One of the circular design guides presented in Madeleine's thesis is design for versatility, "obsolescence in products sometimes occurs not because of physical wear out but because of changes in the tastes and needs of the customers" (Kristin Weiser, 2021). So it made me double think about the possibilities that a product could have when it comes to changing the interface and versatility.

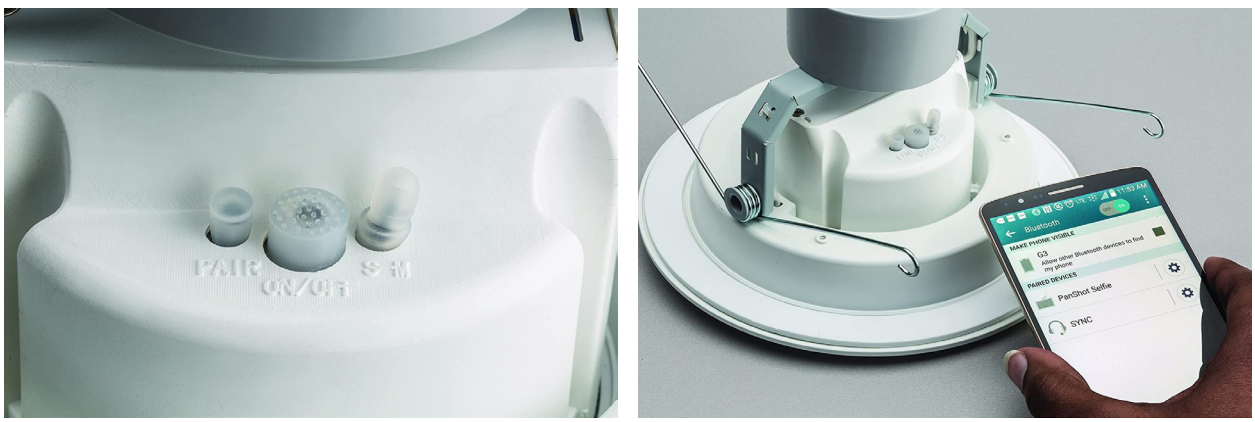


Figure 07. A smart downlight, photo from, Lithonia Lighting, Amazon.

Strategic Vision

A circular economy requires more than just designing a sustainable product through the recycling approach. In this regard, it is important for the company to define a strategic direction for the market. It is also important to consider recyclability. "Generally, it is impossible to recycle a complex electronic product for a hundred per cent, and therefore, much value is lost through the process." (Chapman, 2017) Considering this fact, the Ellen MacArthur Foundation (ibid.) suggests that recycling is not the preferred loop in the circular economy and that greater emphasis should be placed on the inner rings (Figure 08).

The inner loops are where CTM Lyng should step forward and decide about the strategic design behind this project. In this thesis, there is not enough space for the strategic design part; however, having in mind some future scenarios would help a lot in designing products under future developments and decisions. For example, the scenario in which the user would deliver the old damaged downlight to get a discount for purchasing a new one will influence the design decisions of the product and the strategy. Some parts could remain in the cycle, which means the designer should consider a resistance material such as aluminium or have other solutions than material to improve the part. The part maybe becomes more expensive, instead, it is usable for many years and will lead to saving material, production costs, shipment costs and other related expenses in the future.

With these kinds of strategic plans, either CTM Lyng or the other third party can benefit from a closing loop cycle while helping the environment. This is where strategic design and product design meet. I find this notion worth mentioning for this project as a part of designing in a circular economy cycle.

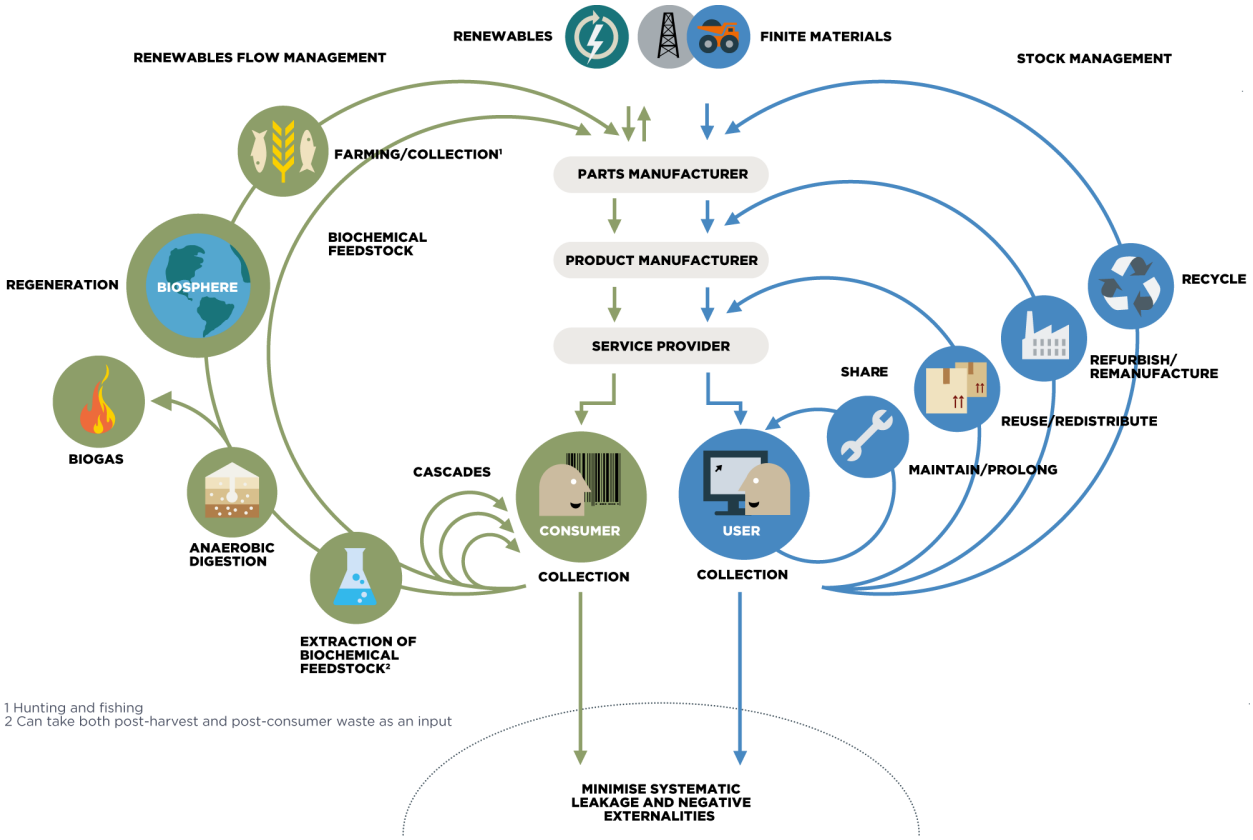


Figure 08. Ellen MacArthur Fundation,

Circular economy system diagram, 2019.

Online Market Review

To become familiar with similar products in the market, I have assigned one part of the project to do deep research into the market. The methodology started by searching the downlights and going through the customers' reviews. This was helpful and provides lots of comments and feedback from the actual customers. I have selected the Amazon website, for instance, to see which downlights are most common and what are the pain and gain points of the current products. There are some facts in rating the downlights:

1. The electrical features are related to the electric board, LED quality and driver quality. The users have admired or blamed the lifespan of the lighting. A stable light without flicking and noise is significant in marketing. People are willing to pay more for a product that saves electricity.
2. The installation, how the users are supposed to mount the product inside the ceiling/ wall, is discussed a lot in the comments. The installation priorities were related to easy or difficult mounting, the tightening possibility, high-quality parts and springs that last for a long time.
3. The design in terms of aesthetics was the less important factor. Instead reducing the glaring beam in the room, applying versatility, and specific features such as smart options are presented. The smart function, syncing the lights with the mobile app and controlling them remotely, is a valuable option for downlights. These kinds are features known as new trends in the lighting industry which have been noticed quickly and making satisfaction for the users.

In addition to Amazon, I've found the other websites and domestic competitors by asking from the company and internet research. I wanted to figure out what are the existing similar products in the market. Is there any company in Norway that produces the downlights with the circular economy context? What are the considerable factors for customers while purchasing this product? Overall, this method helped me answer numerous questions I had in mind.

I continued the benchmarking as long as the timeline allowed me and I felt there was enough information and nothing had been left behind. The result of the online market review has been analysed in the Miroboard. I have used them as a back and forth process with the ideation part.

Below is a list of the most impressive achievements during this research:

1. Most of the downlights are made of metal especially aluminium and fewer of them have been made of plastic. The common type of plastic for downlights is PC.
2. Light beam angle/ diffusion is an important aspect, the more the better.
3. In almost all of the downlights the springs are used for the mounting function. A few companies made downlights with a different mounting function (C clip, for instance).
4. Some downlights have external drivers but some have integrated ones.
5. The downlights are almost similar in the outer part that is visible to the users.
6. Some downlights are fixed and some else adjustable.
7. Most of the downlights are in black or white, very few are chrome, silver and bronze.
8. Some downlights have a battery as their power source.
9. Minimizing glare is important in design.
10. Dimmability is important.
11. Flicker and noise-free is the focus of the ads.
12. Versatility is presented as a valuable factor.
13. Reliable safety is important for electrical products such as downlights.
14. Smart features such as syncing with an app are important, Some smart features are: making the specific schedule to turn off/on recessed lighting, control recessed hue light, remotely control the smart downlight through the APP, share other devices that the LED can light together, memory function that keep the last setting, music sync.
15. Several downlights have colourful filters for different hues.

I am using this on ceiling as a replacement for an old can light that stop working. Installing this one is fairly simple and straight forward. I was able to get the fixture to sit pretty tight against the drywall ceiling. You have to get the app to work the colors and connect to WIFI. Pretty simple and the app is good. Brightness is average and colors look nice.

Material: metal

costumer review: These were so easy to install and look great. They screw right into the existing recessed light socket so there's no need to switch out the can. I have 4" cans that had incandescent lights and an aging tension ring cover. All I had to do was take off the old cover, unscrew the light, and screw in the new set (light integrated with the tension ring), then pop it in.

Installation is simple if you have existing recessed lighting. You basically just screw the adapter in the light socket, then connect the light to it, and push it into place...done. Not so fast, though read on. Unfortunately the physical setup was the only thing I was pleased with.

https://www.amazon.com/Smart-Recessed-Lighting-Downlight-Compatible/dp/B07WHBZ6T7/ref=sr_1_1_sspa?keywords=lumary+downlight&qid=1645609801&sprefix=lumarry+down%2Caps%2C202&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUE2U1hSRDRNQTZXS0QmZW5jcnlwdGVkSWQ9QTA2MzQwMjAxNVFQMkhLMzJSRkNOJmVuY3JcHRlZEFkSWQ9QTAxNTA3NTEyNTdESFc4Q1AwRk5WJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==

The plastic that holds the clips break, while installing they break and if they don't break then they will break after installation, they were popping after they were installed , complete rubbish product

Material: plastic

"I cannot recommend this light. I've been installing various brands of retrofit recessed lights the past few months. This brand is by far the worst. The springs are too weak and maybe a design flaw. The light does not press against the ceiling. No matter how I try it slides down and will not sit flush. Also the baffle trim is all plastic. Would suggest finding an aluminum one. Very frustrating to try to install these lights."

The lights are amazing and install in a snap but three of the 12 have small cracks and the springs fall out. The other 9 are in place or work GREAT!

costumer review: Certain recessed light ports were a little difficult to fit because the springs kept getting stuck into holes but once I had them position correctly they went in and stayed in with no issue.

costumer review: One set has the "C" type clip that seems to be what most can lights have now, and the other set has semi circular punch outs that receive the spring arms. Both types were a snap to install and are holding tightly against the ceiling.Flush mount is much nicer looking than the old can lights.

the price is important for the quality of the product

Overall I liked the appearance of the lights, but the design of these lights is terrible. 11 of 12 of the lights have since broken on me since installing them in January 2021. The spring clips that hold the light into the recessed can housing are an incredibly poor design. The springs are assembled into a plastic piece that protrudes from the backside of the light trim and is secured in place with a sealant or caulk of some type. If these spring clips get sideloaded even a little bit, the springs get torn free from the caulk, and there is no way to replace it (without recaulking it yourself). I used these lights in a basement remodel. I had no issues during the initial installation of the lights after I completed electricity and framing. But about half of them broke when I had to remove the lights for the drywall crew. The remaining lights broke either when I went to reinstall them, or when I had to remove them again to paint the ceiling. Now because the clips are broken, the lights sag down from the ceiling and look absolutely terrible. I am somewhat surprised that this company decided to use an adhesive vs. securing it in place with a sheet metal bracket and a screw. A screw and sheet metal bracket are very inexpensive components for a mass-produced item. Glueing something in place typically takes time and a human doing the glueing, so it's somewhat surprising to see this used over a much more robust assembly method.

Figure 09. Some of the online reviews from Amazon's customers.

Figure 10. Online market reviews.

Figure 11. Online market reviews.

Figure 12. Online market reviews.

I have continued online market review while jumping to the next phase and having some ideas in my mind. This time the search keywords were more about the aesthetics and adjustable lighting in the market. I realised that some of my ideas have already been designed and produced by other companies. I found ' Architonic' with a collection of designed lighting that is worth looking at. It has amazing inspiration for me to figure out how creativity and aesthetics can play an important role in LED downlights.

During the last stage, I made a priority chart to value each product by its circularity and functionality. This method was useful to see the area where my final product could be placed and to see which other products are there at this stage. The biggest challenge in categorizing the products was to find out the technical information. Most of the websites have presented photos or videos of the products but it was difficult to recognize the different parts, how the parts are joined together and what material is used for each part. So for these kinds of products, I have considered the most impressive feature that I want to use in my concept.

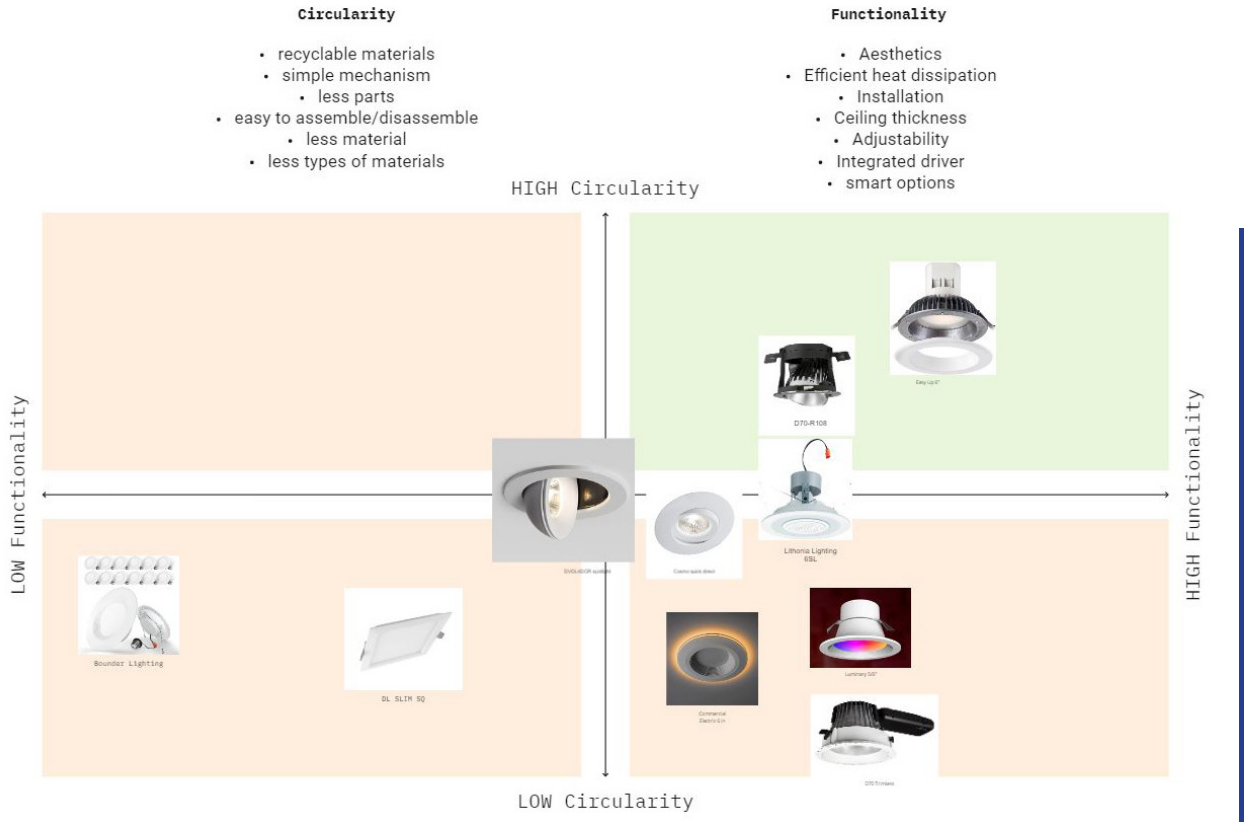


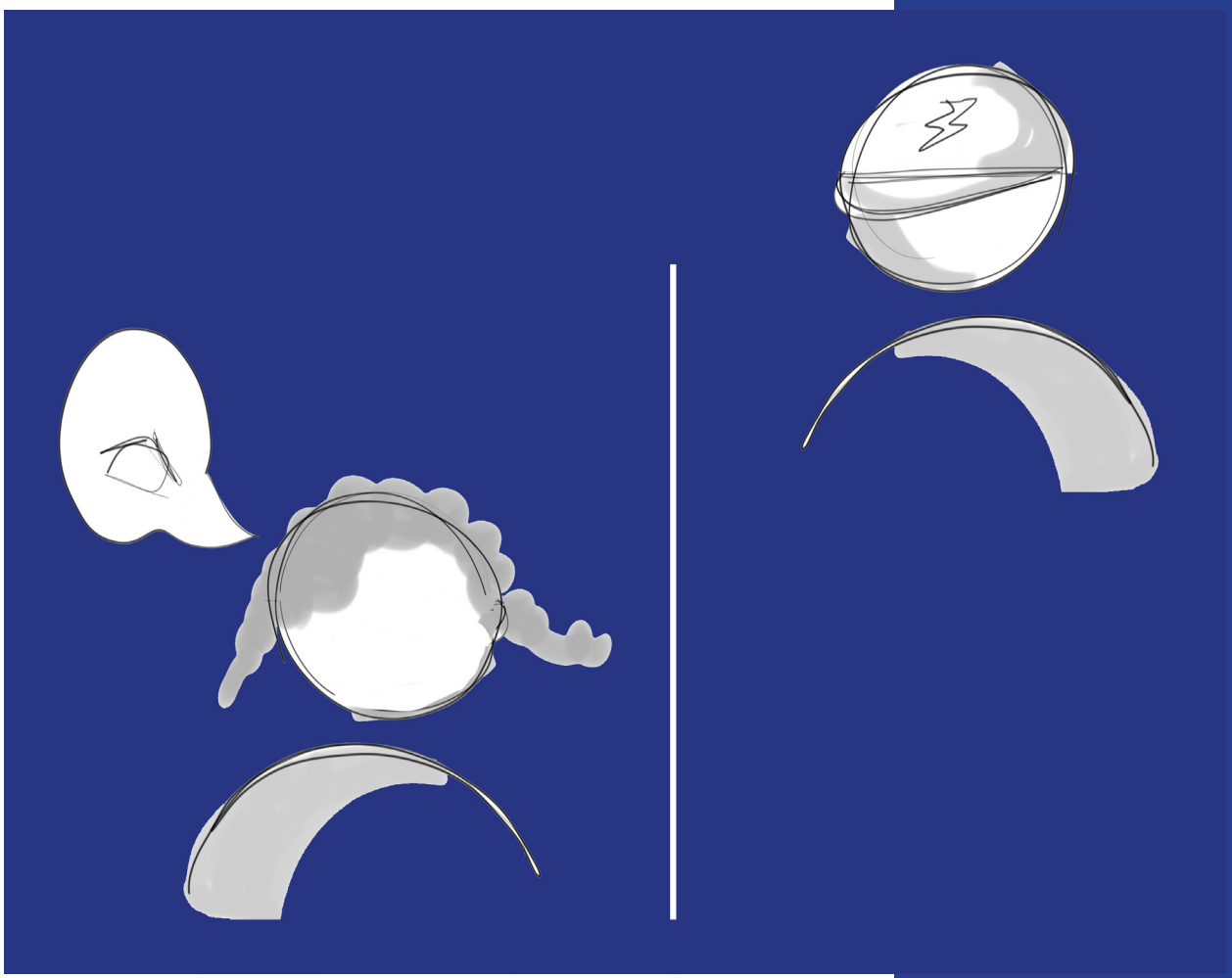
Figure 13. priority chart.

End-User

As it is mentioned earlier, CTM Lyng is a business to business company and the customers are Wholesalers. Whenever the light fails or gets a problem, the end-user has to call an electrician to fix the problem. It means that the final end-user is not in touch with the product except in the outer part (visible part) and its lighting functionality. Professional users are the main focus of the project. They ship the product to the customer's place, assemble it and mount it to the ceiling. It is, therefore, important to discuss the gain points and pain points of the product with them. However, the vision of the project is circularity, I can involve these professional users in the process in order to improve the installation process and know the difficulties they have with these kinds of products. There are always some efforts for satisfying the users.

Regarding the final end-users, it should be assumed that the aesthetics and the functioning effects should afford their needs and provide enough satisfaction. To extract more data, I didn't limit the project to Norwegian customers. In the online market review section, the reviews from the final end-users are international. Moreover, in some countries people used to change the downlights themselves, therefore this customer feedback could be considered by both the users and final end-users.

For a better understanding of the process, a downlight passes to be in the customer's houses, I've considered a user journey map.



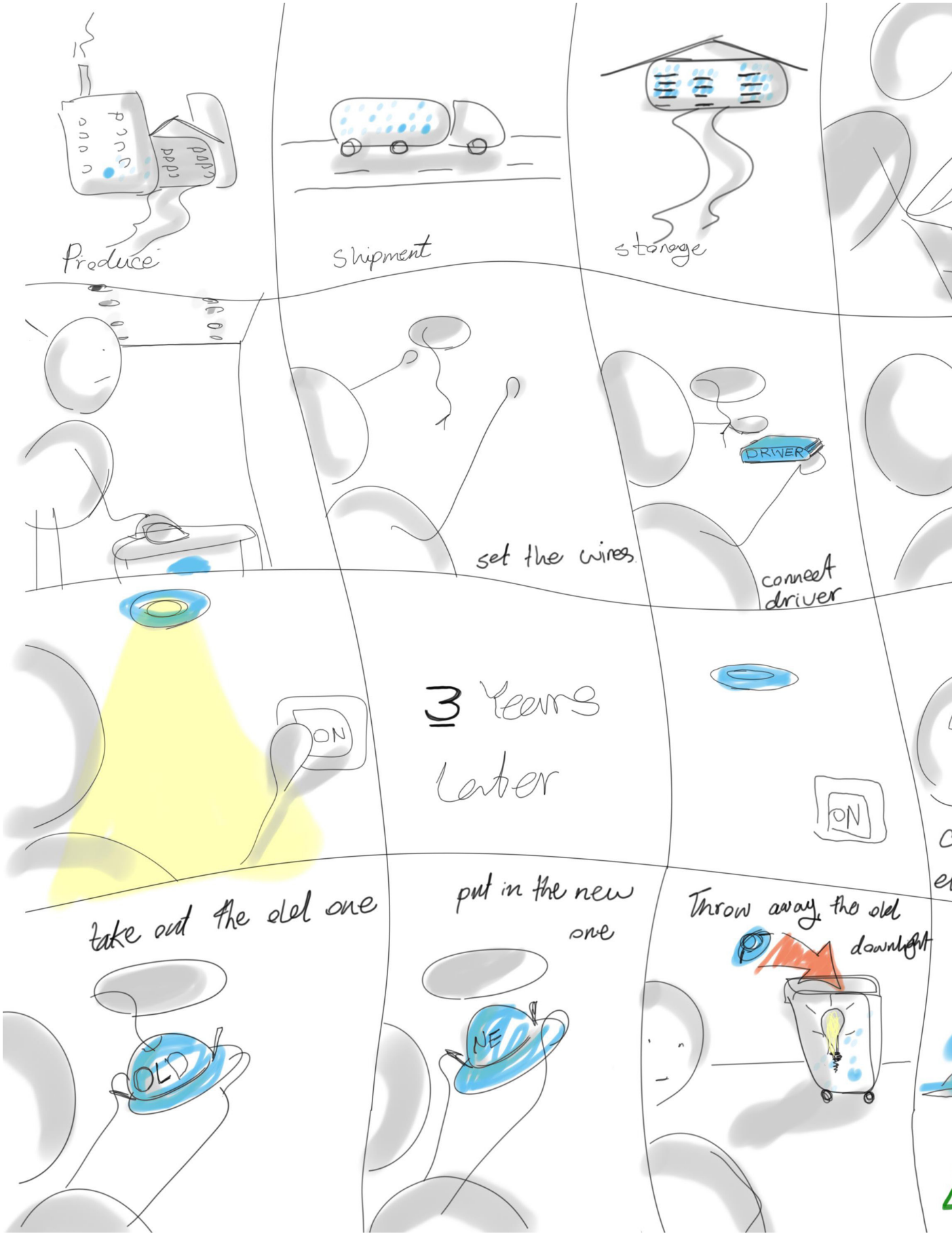
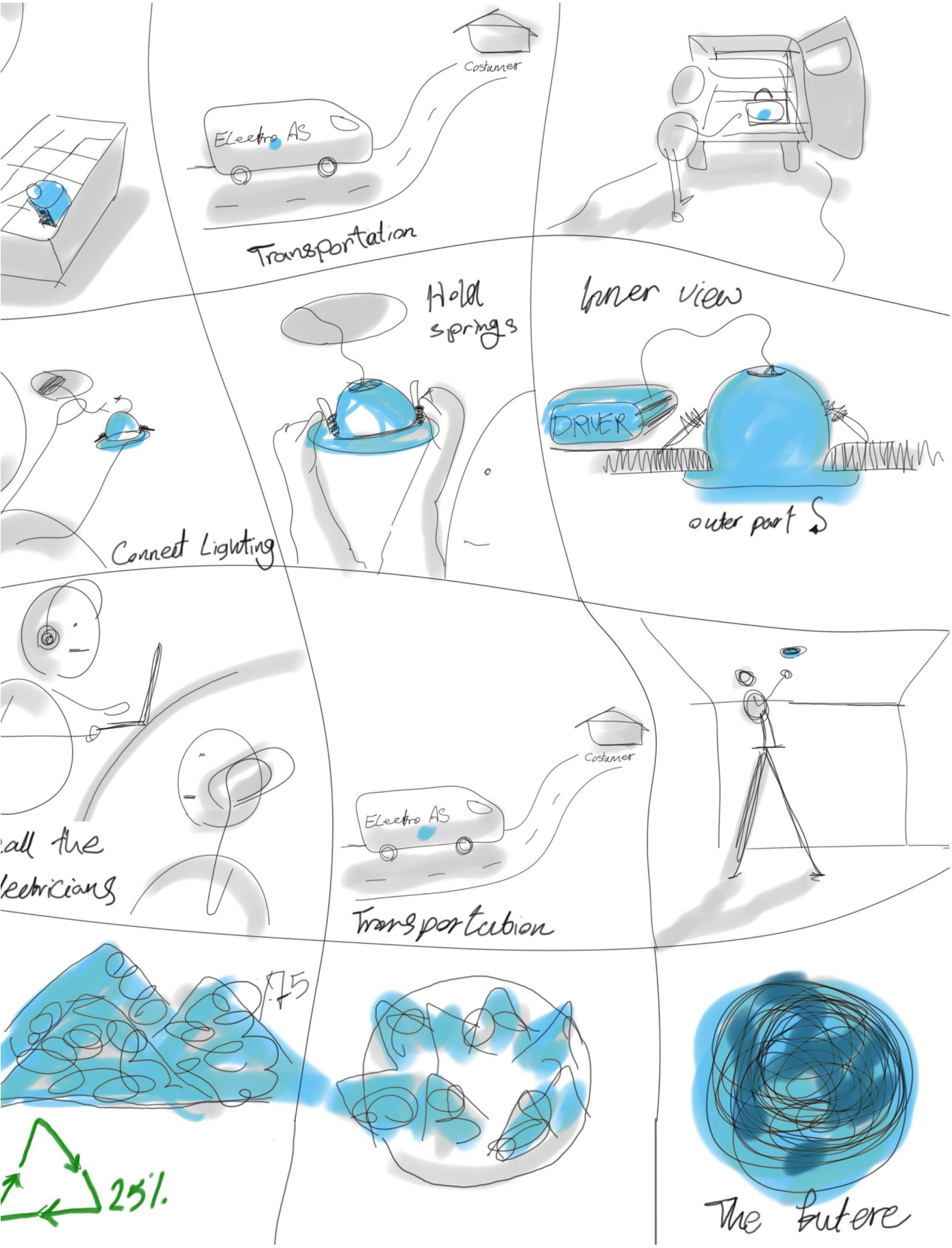


Figure 14. User journey map.


Costumer
Eleetro AS
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Product part analysis

This section includes the practical research that I have done to become more familiar with the product and analyse different parts. I have considered the types of downlights that are more common in the market. The downlights are grouped by function (fixed or adjustable) and technical features (external driver or integrated driver).

- Fixed downlights: The most basic and by far the most popular of downlight types.
- Adjustable downlights: The type of downlights that could be adjusted in different directions.
- Downlights with external driver: the electrical driver that is usually attached to the LED downlight by the wires.
- Built-in driver downlights: The electrical driver that is integrated inside the LED downlight housing.

Figure 15. Fixed downlight.

Figure 16. Adjustable downlight.

Figure 17. Downlight and driver.

Figure 18. Integrated driver.

The part analysis started by disassembling the two recent products of CTM Lyng in parallel with the internet search of the pictures and videos showing the exploded view of the product. I have taken apart all the pieces in the mentioned downlights and looked carefully at the details. (Figure 19 & 20) In each of the products, the quantity of the parts was more than ten pieces which is a lot and makes the product more complex for producing, repairing, reusing and recycling. Both of the downlights that I went through were adjustable types. Looking at downlight A, it was adjustable by one axis and the second one was 360° adjustable. Through the analysis and meetings with the company, I have figured out that designing the product from scratch would not be convenient, therefore, I have decided to develop the recent products by keeping some features and making them suitable for the defined requirements. The number of the parts are same in both products, but product B owns smarter design ideas.

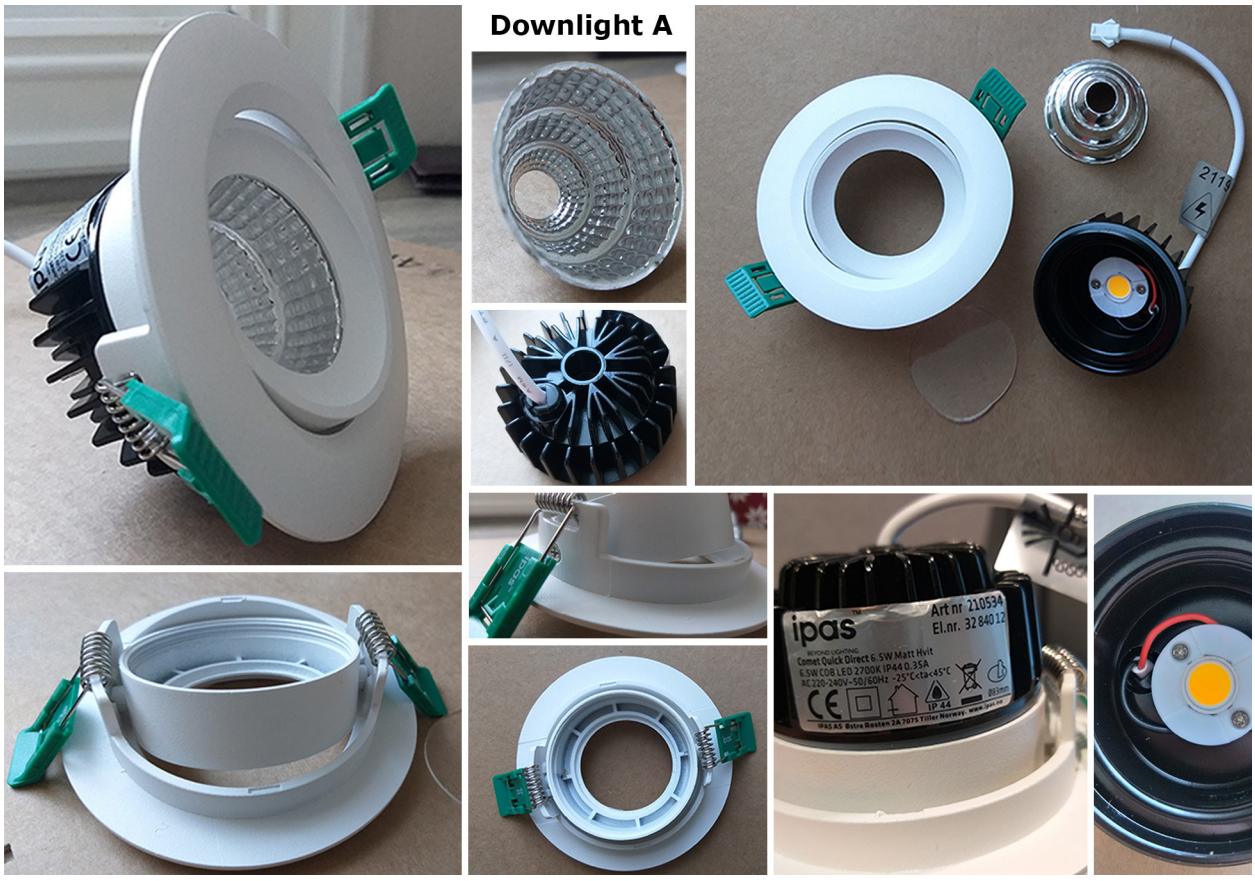


Figure 19. Comet downlight, CTM Lyng product.

Figure 20. Cosmo downlight, CTM Lyng product.

Below there is the list of the parts with a brief description of each part, its features and purposes.

A. Structural parts in downlights:

The mainframe: The main body is the most important part. It holds the other parts and is also attached directly to the ceiling. In most downlights, this part is made out of metal (mostly aluminium), however, some new products are using plastic and plastic coated in aluminium as the main body. The reason that using metal is more common than plastic is that this part is in connection with springs and needs to have enough strength. It is also important for a downlight to transfer the produced heat by electricity voltage and LED temperature. So metal has been presented as a safer and more heat resistant material for the downlights. There is usually a heat sink area on the main body to keep the body cooler by transferring the heat away from the high-temperature area (LED chip) to a low-temperature area. In the adjustable downlights, this part is divided into one main body and another rotational part that usually connects with pins or screws.

Reflective cup: This part usually has a shiny silver colour. The colour and reflection aspect of this cup directly affects the brightness and temperature of the light. It has different protrusions and angles that cause a more light diffusion and reduce glare in the space.

Front lid: There is tempered clear glass on the front side of the downlight. The lid is responsible to keep the lighting safe, waterproof and dustproof. In some cases, the manufacturers are using matte glass that makes it possible to have softer light which minimises glare in the space. The matte glass makes indirect light shades. This matter is also more convenient in the production process since it omits one part of the product (reflective cup) but many customers still like to see the light and shade's effects in their homes. On the other hand, downlights with matte glasses are common for commercial buildings and workplaces, said Vidar, the project manager.

Downlight B has a plastic around the glass that helps to fit the glass better in its place and also improves the waterproof and dustproof features.

Back lid: In downlight A, this part is directly fastened on the main part that is completely invisible to the final user. The LED holder is mounted on its inner surface and the wire is brought out of the back lid to connect to the electricity driver. Looking at downlight B, the back lid (the black part) has screw threads for attaching to the front ring.

Two springs: Springs are the most common types of mounting the downlights to the ceiling. Springs are always made of metal since they should be strong enough to keep the downlight tightly in the correct place and flexible enough to install and uninstall the lights. In some of the downlights, C clips or friction clips are used, however, none of them is still as good as the common ones.

Springs' cover: These plastic parts are covering the part of the spring that is in touch with the hands of the electricians and protect them against probable damages. Another function of these tiny parts is to reduce the sudden hit of the springs on the ceiling during installation and protect the thin gyps boards from breakage.

Screws: The screws connect different parts together.

The LED holder: This part is usually made of plastic and keeps the LED chip. It is fastened to the housing by screws.

B. Electrical components:

LED Circuit Board/ LED Chip: The mainboard for holding LEDs. The new types of LEDs are called LED chips that contain semiconductor layers.

Wire: The electricity cable.

Electric Driver: An LED driver is a self-contained power supply which regulates the power required for an LED or array of LEDs.

Reflective cup: This part usually has a shiny silver colour. The colour and reflection aspect of this cup directly affects the brightness and temperature of the light. It has different protrusions and angles that cause a more light diffusion and reduce glare in the space.

Design considerations

The part analysis enabled me in finding the most essential factors to consider in the overall design. It gave me a better knowledge of which components needed to be developed and which I could maintain as they were in the prior edition. I need to think about two major design challenges.

A. The mainframe is the most critical component, which I must develop and modify to meet the new material and task requirements.

B. Another design issue is whether to create new springs or to eliminate them and come up with a unique solution. The design of the springs was considered critical since we want to make the new mainframe of plastic, and regular springs were not an appropriate choice. As is achieved in the online market review, attaching metal springs to a plastic body frequently results in breakage in joints.

Interviews. 01

Due to project timing limitations, the interviews have been started from the discovery phase and continued until the define phase. However, it is important to have all interviews in the defined phase, before developing ideas, it was more time-efficient to have some parallel activities. For this reason, I have split up the interviews into several parts. As a reflection, I assume a new experience to have the interviews alongside the project. It was more focused without unnecessary discussions.

During the project, some of the questions in interviews have been developed because I got familiarised with the different aspects of the project and each phase required specific types of questions.

Vidar Løw- Owesen, CTO, CTM Lyng

I have talked with the project manager of the company. Firstly, I have presented him with a brief description of my design process, and what I have done so. Then he proposed his attitudes regarding the project and my master thesis. He introduced the last product of the company with details. He raised the most critical points about the product and mentioned that the new product shouldn't have fewer features than the recent company's products. Of course, he was aware that regenerated materials are new with unpredictable challenges.

Vidar also briefly talked about the history of the lighting they had in the company and the development process that they have passed. In the meeting, I realized that there were a lot of design concerns in Vidar's words that I need in my project. One important notion is that to remain our product in the market and compete against the bigger competitors, I have to think about the most important feature of the final product. This product must survive for a long time to be confirmed by users and highlight the hazardous consequences of the non-circular products. I have to imagine a story behind its design that could be used in marketing as well. What are the specific features that persuade the customers to buy this product? What design considerations are there to solve the current issues in the products. Some of the small perceptions in this meeting make me think about some missing points in my process. Considering the steps in the installation process, for instance, is an important part that I had missed in my project. The usual scenario in installing lighting in a building is that the carpenters make the holes in the ceiling, the painter paints the ceiling and finally, the electricians install the lighting. But this scenario is not always in order, sometimes there are some misarrangements in the steps. It is desirable that the downlight get fit into the process even when there are some unusual circumstances. One circumstance is a cut out hole that has been painted and got uneven edges. The designer can keep a gap between the inner surface of the downlight and the ceiling. With this small detail, we save both time and the cost and make the customer willing to buy our product.

Vidar also pointed out the business model of the project. This project is a unique approach to the production and circular economy in the lighting industry. The final cost, therefore, would be higher than the existing products and the first customers in the model would be Norwegian official organizations and government buildings that are willing to spend money on circularity.

The private customers are the second market that comes after and it is not the main concern of the project for now.

Frank Robert Husby, Engineer & Electriacion, CTM Lyng

Talking with Frank, an experienced electrician and product developer, who installed the downlights for many years was important for me. Alongside the conversation, Frank responded to my questions from his technical perspective which was beneficial. Like every other technical guy, he concentrated on the current product and told me first that the recent product doesn't have any problems, "it is developed enough now", he said. He mentioned that the only problems with the current products are the specialised problems related to boards and components and this is something out of the designers' hands. After raising some of the issues such as springs and difficulties in installing the external driver to the downlight, he believed there are several things that I might be able to improve. He pointed out the driver and told me that the overheating in the drivers always leads to the shorter lifespan of the products. Here are some of the Q and A from the interview:

1. What difficulties do you have while installing the downlights?

   - There is not a very serious difficulty, they are easy to mount and the previous problems such as connecting the wires have been solved by the new product.

   Have you ever broken or damaged a light while installing it?

   Yes, it happened to me several times. The downlights are usually breaking from the parts that are connected to springs.

2. What do you think about the springs? do you have any problem with that?

   Too strong, damage the ceiling. Sometimes the caps run away from the springs. They usually hurt the hands and fingers but this is normal and there is nothing to do with that.

3. What is more challenging about the downlights?

   I think connecting the cables was the most challenging thing that has been solved in the new products. About the current product, I would say installing is easy but taking the downlight out from the ceiling is very challenging and more difficult.

4. What is the most technical challenge for the product?

- The driver is the part that gets very hot and influences every component on the PCB board. So overheating in this product I can say make major technical problems and lead to a shorter lifespan of the product.

An Important Issue

I have to raise a fact in this section that the downlight we are designing, should be easy to repair and easy to disassemble according, but we should be aware that this easy to repair product doesn't seem like a DIY product and don't encourage the users to do it by themselves and not by the experts.

Why is that important? Firstly, it is illegal to repair electrical products by someone who is not an expert. There might be lots of risky faults through this process. Secondly, CTM Lyng will arrange a vast domain and make the infrastructure for repairing and reusing the products. The new lighting would respond to 7 years of guarantee and if the individual tries to fix the light by themselves, then the company is not aware of the changes. Are they following the standards anymore? It is more likely for the users to damage the product instead of repairing and fixing the actual problem.

How we could solve this problem?

Solving this problem is possible in both designing and strategic decisions. In the design phase, I have to think about a product that is easy to disassemble but easy for the expert not easy for the end-users. Maybe sophisticated design solutions? Maybe the product requires a specific tool to fix that only the experts could have? This is a good point but the design itself could not afford this problem. Making the product more complex adds more energy and time and gets it out of the circularity guidelines. It wouldn't be convenient anymore to take time for repairing the light. So if the strategic decisions perform together with the design, then the future goals would be nearer to reality. Another idea could be considered a type of sealing for the product so if the customers try to repair this product they have to break the seal and the product gets out of guarantee.

Circularity Conclusion

During the design process, I attempted to collect as much information as possible regarding the sustainability and circularity concerns. In fact, there are many concerns that a designer could address to design sustainable products. For this purpose, I have used the mind-map method and gathered the five influential facts. Each of these five areas has been divided into smaller parts. This mind-map then has been narrowed down and defined the importance of each factor in this master thesis.

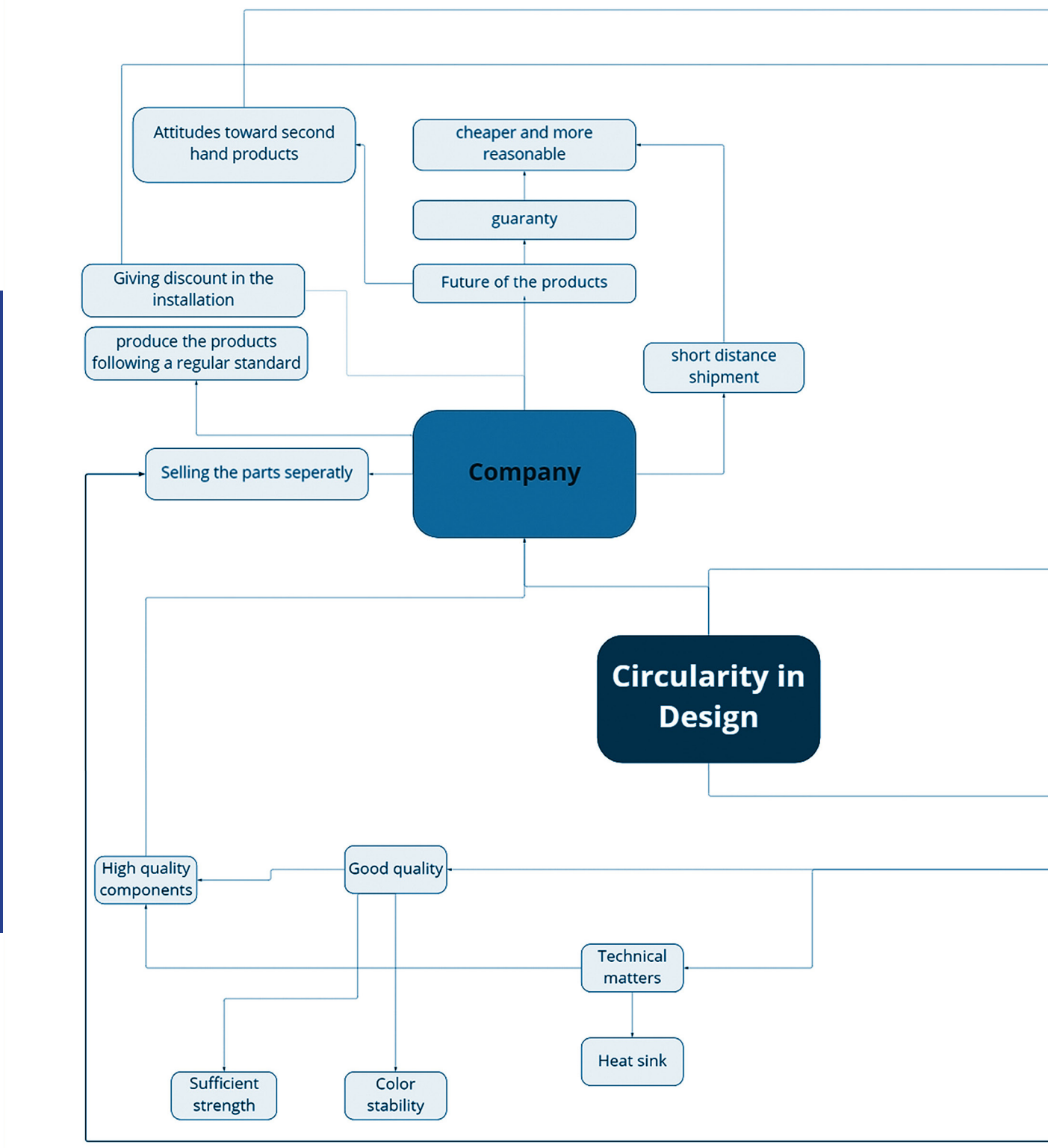
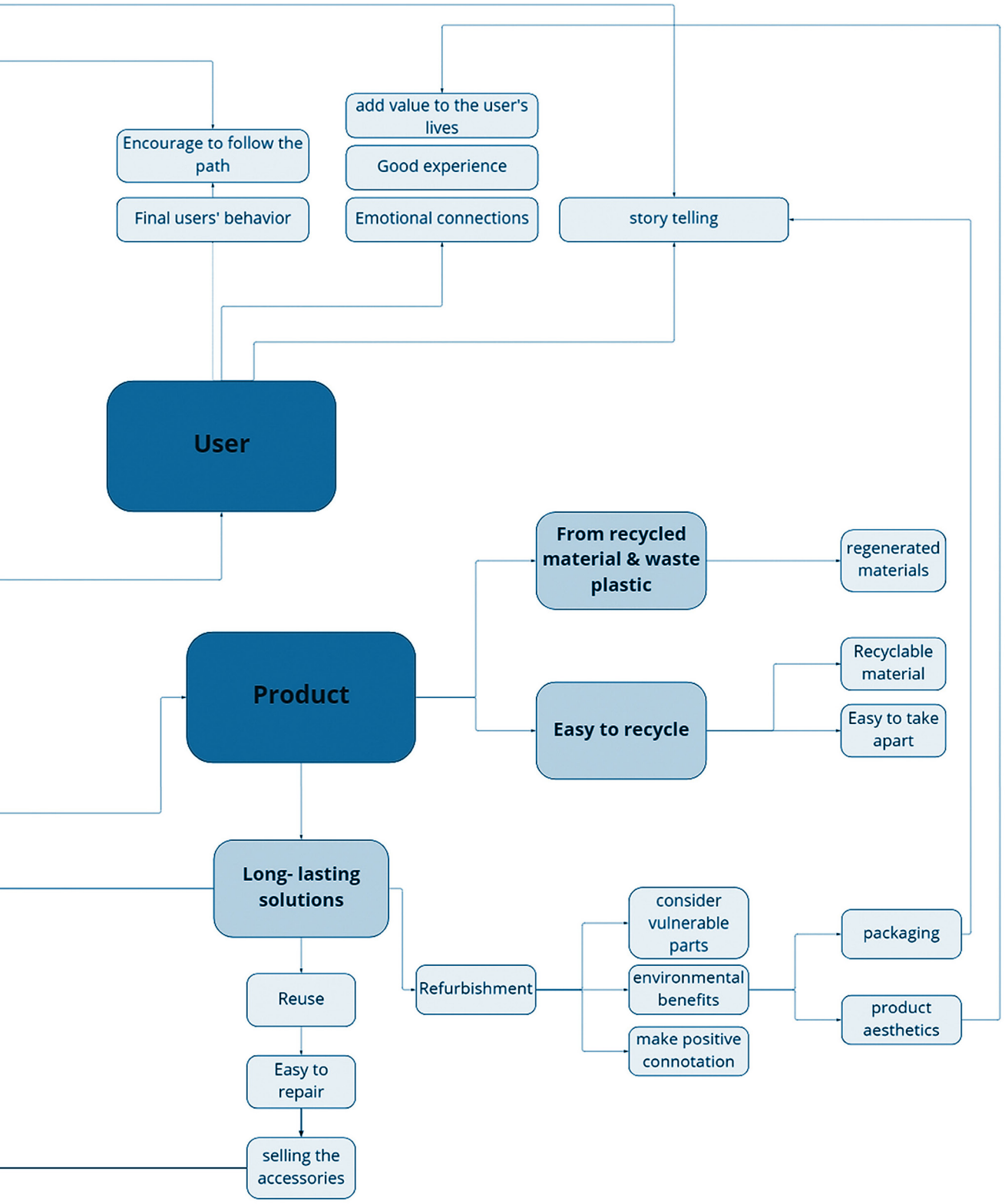


Figure 21. Circularity conclusion.


add value to the user's lives
Encourage to follow the path
Good experience
Final users' behavior
Emotional connections
story telling
User
From recycled material & waste plastic
regenerated materials
Product
Recyclable material
Easy to recycle
Easy to take apart
Long- lasting solutions
consider vulnerable parts
packaging
Refurbishment
environmental benefits
Reuse
product aesthetics
make positive connotation
Easy to repair
selling the accessories

Project Areas Conclusion

At first, I find it challenging to focus on the exact topics that the project should cover. I was jumping between different areas and didn't have clear thoughts for each. So, another mind map has been created to collect the project-related issues that I wanted to consider in the project.

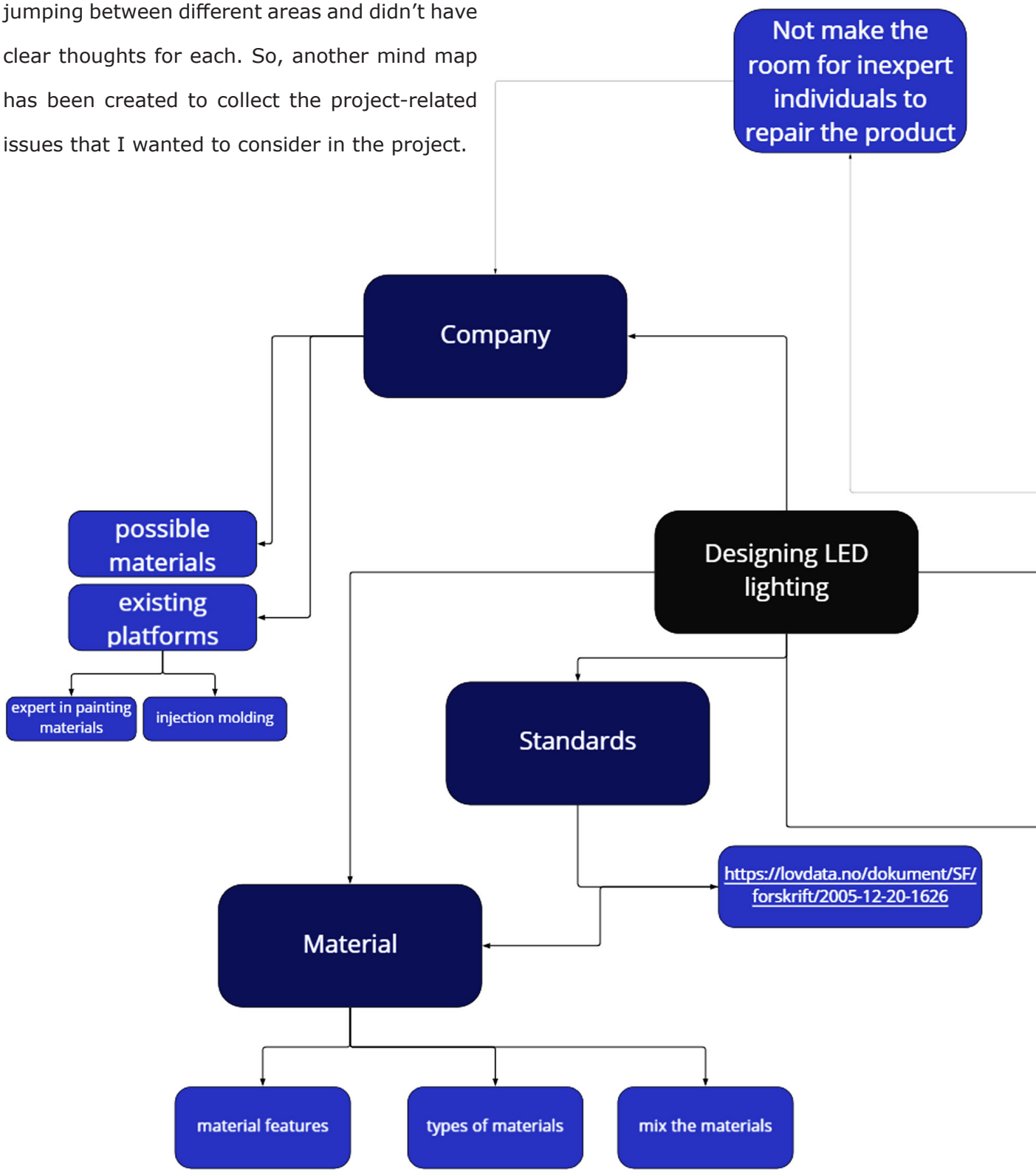
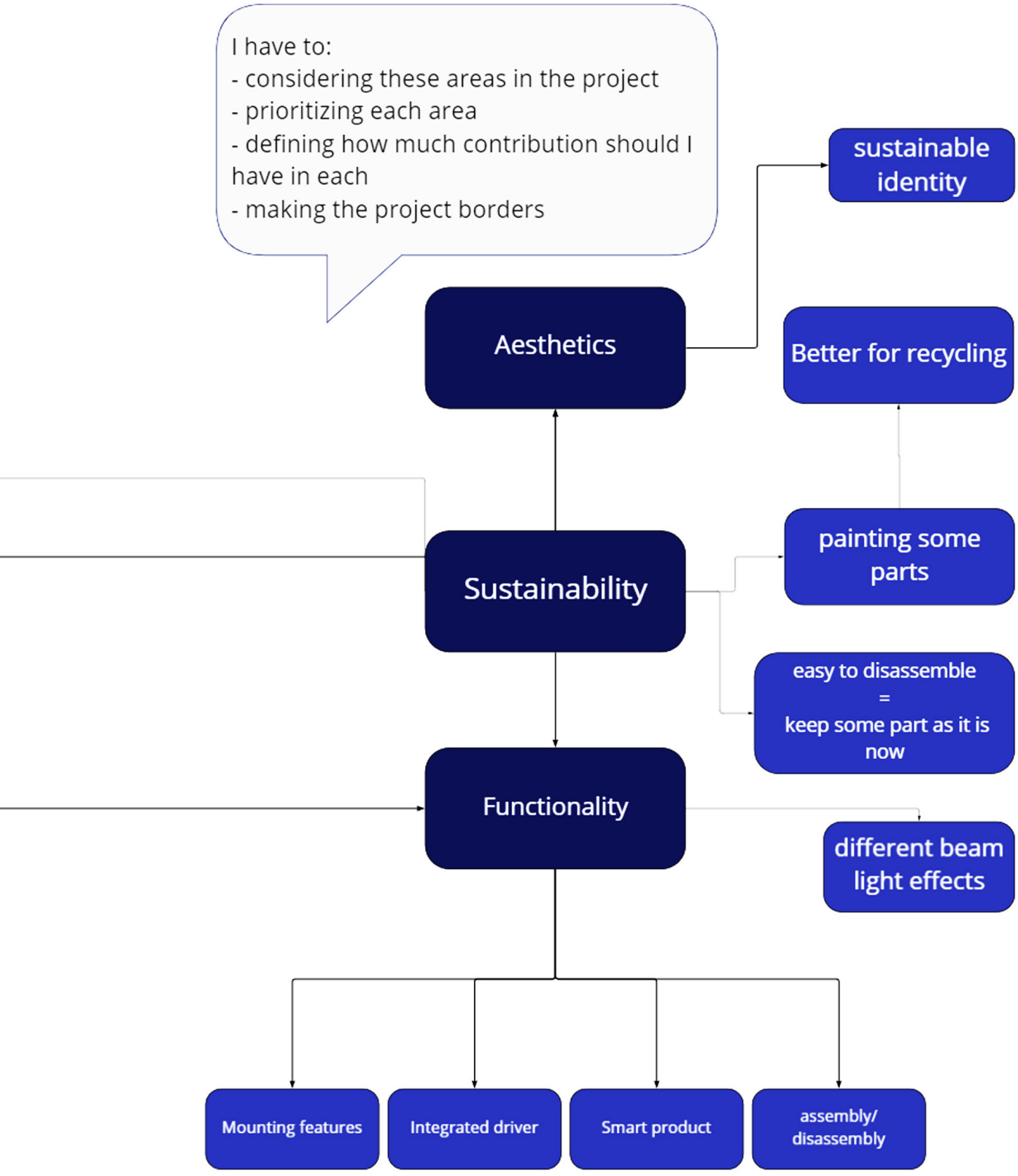
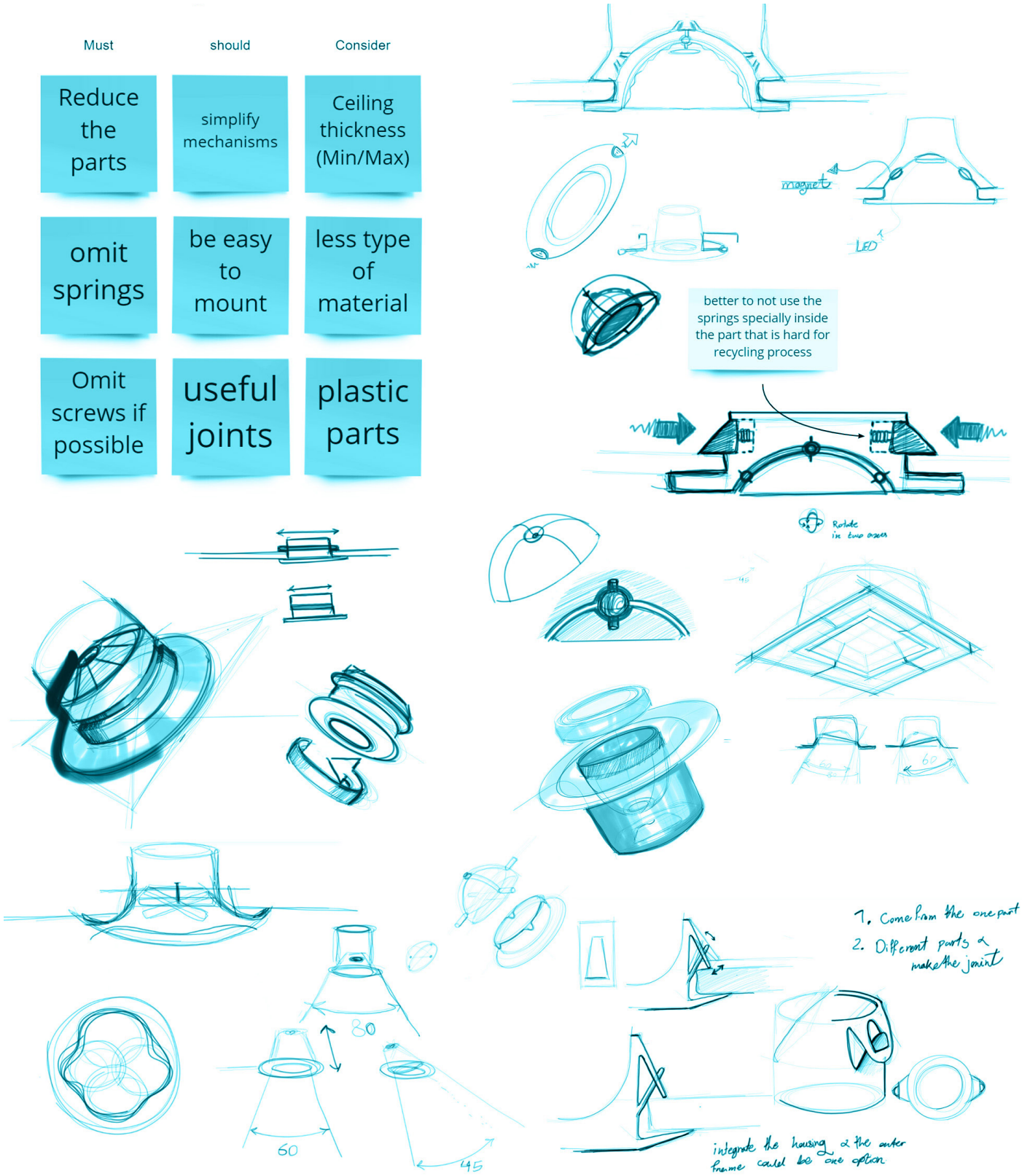


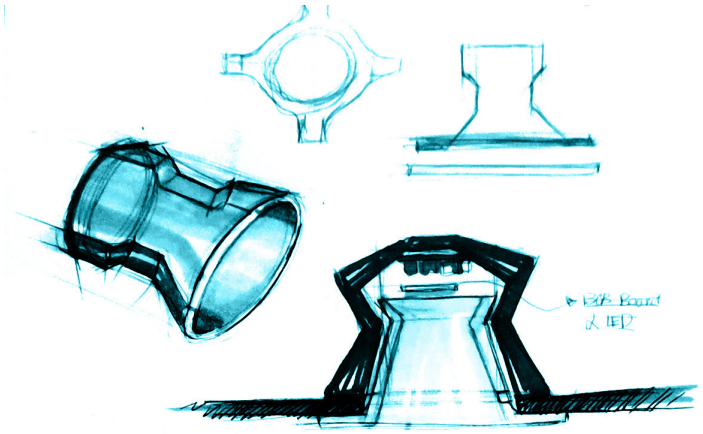
Figure 22. Project approach conclusion.

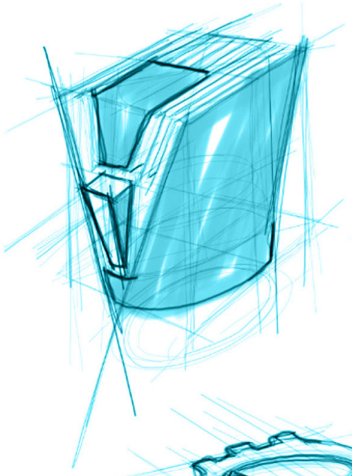


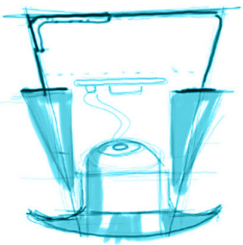
Initial Sketches

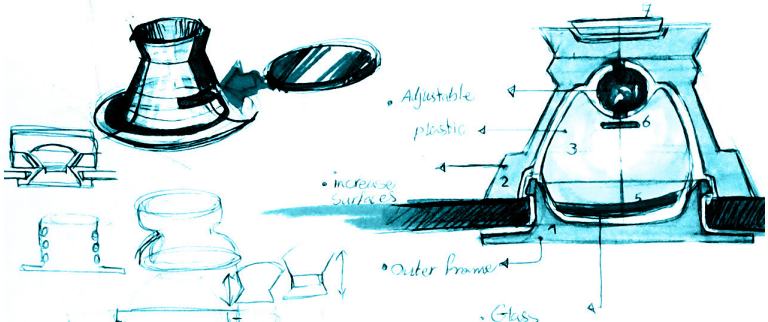
Sketching and ideation have been started at the very beginning of the project. The purpose was to record any ideas that popped into my mind through different stages. During this stage, the main research and thoughts were about design parts that are simple and functional. These initial ideas also followed primary design guidelines that I've defined by project achievements.

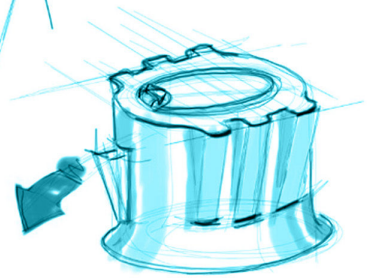


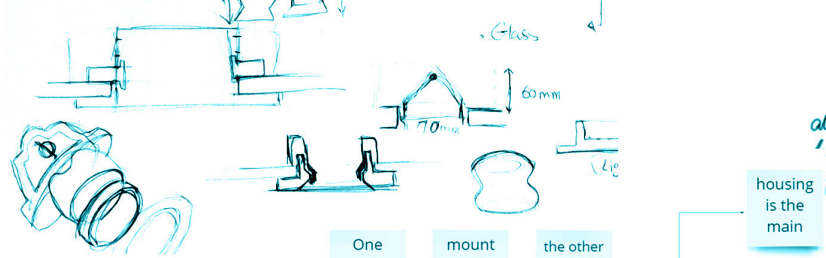


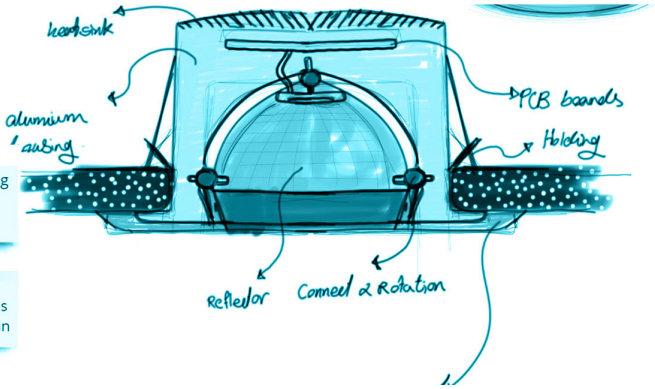




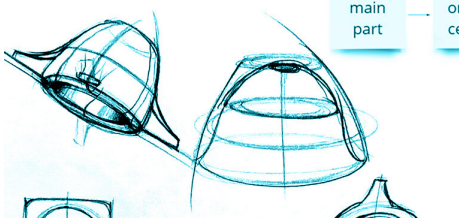


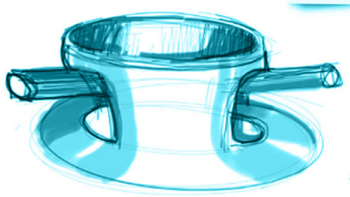


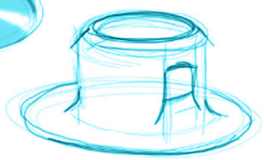


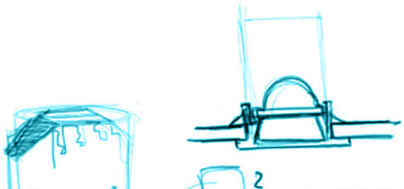


One main part → mount on the ceiling → the other parts will attach → housing is the main / outer frame is the main

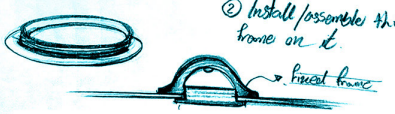


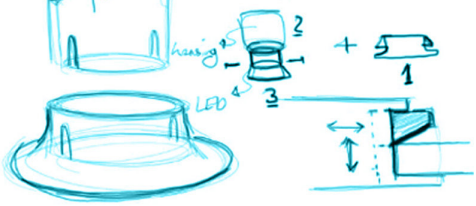


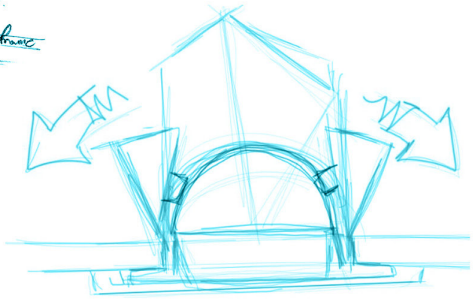


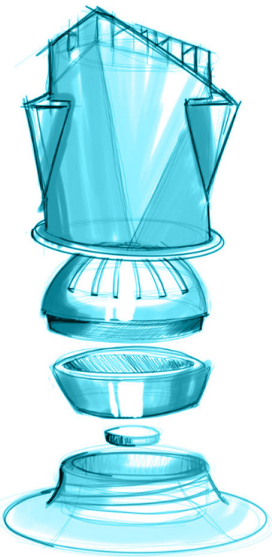


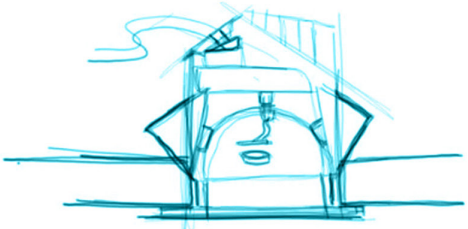
① Fixed structure on ceiling part.
② Install/assemble the outer frame on it.



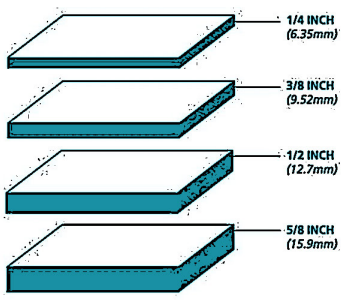








DRYWALL THICKNESS




1.
2.
3.

Findings of Discover Phase

1. The company’s requirements and the project areas should be combined and prioritized.
2. In the circular economy guidelines for design, some of the factors are not possible by the design itself and demand strategic efforts.
3. Emotional attachment leads to a value for customers but for downlight maybe it is not a value. The customers and end-users are different for this product.
4. Online market review highlights crucial data, that can be used in the ideation phase.
5. CTM Lyng downlights are easy to disassemble.
6. There should be a better alternative than springs, I should consider them.
7. LED Drivers make more concerned in terms of heat and technical problems.

Define

In this phase, the achieved knowledge including the research, interviews, company’s requirements and all the previous steps have been collected and defined.

Design Brief

This design brief consists of two groups of requirements. The first one which is the "Should" group refers to the requirements that the product should exactly address them. The second group named "Could be" are the features that are the ideal goal of the product, they are not impossible to achieve but need more time and effort. For this reason, it is perfect if the product responds to the requirements in the second group as well. I have considered these design guidelines as the principles of the product and use them to narrow down ideas and develop them.

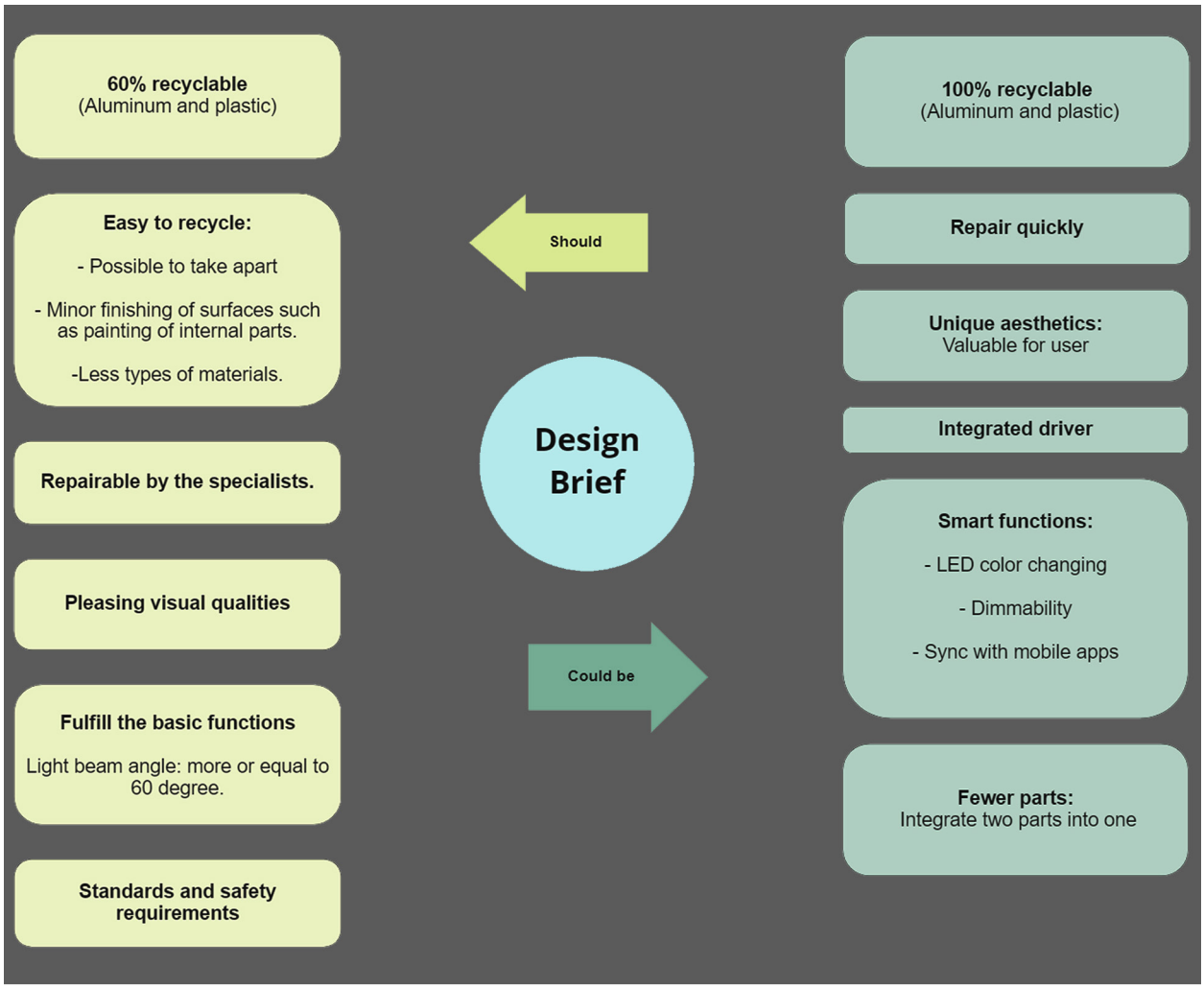


Figure 23. Design Brief.

Recyclable Parts

When it comes to redesigning a product, it is important to consider the previous versions and think about the parts that need to be redesigned. I've attempted to analyse the two types of CTM Lyng downlights in the discover phase and now should define the material of each part to find the possibilities. I should consider that not all the parts would be possible to produce with recyclable materials because of technical limitations and company infrastructure. However, with some design solutions and strategic plans, some parts that are not possible to recycle today could be reused in other products to extend the lifespan and prevent a mass amount of non-recyclable products. The illustrations indicate my estimation of the materials for each part but it might change alongside the project.

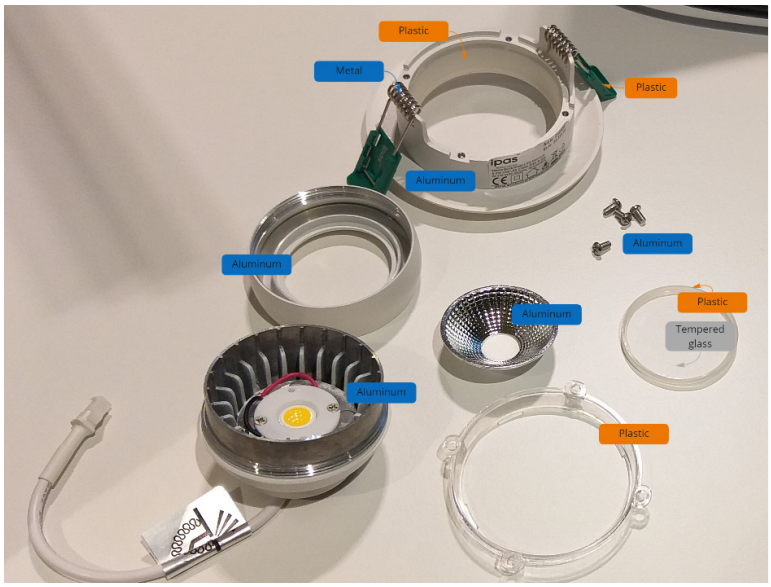
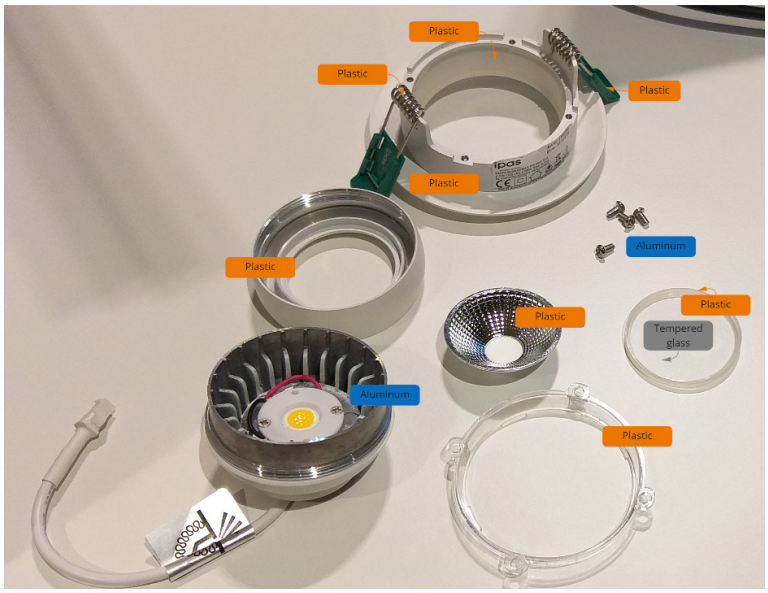


Figure 24. The materials of the current downlights



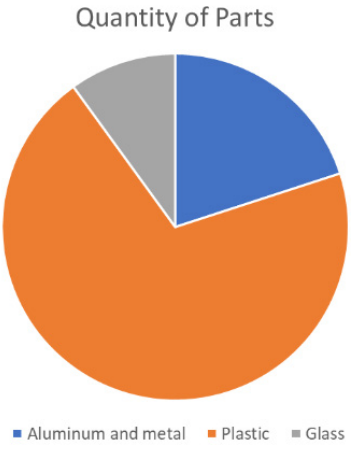
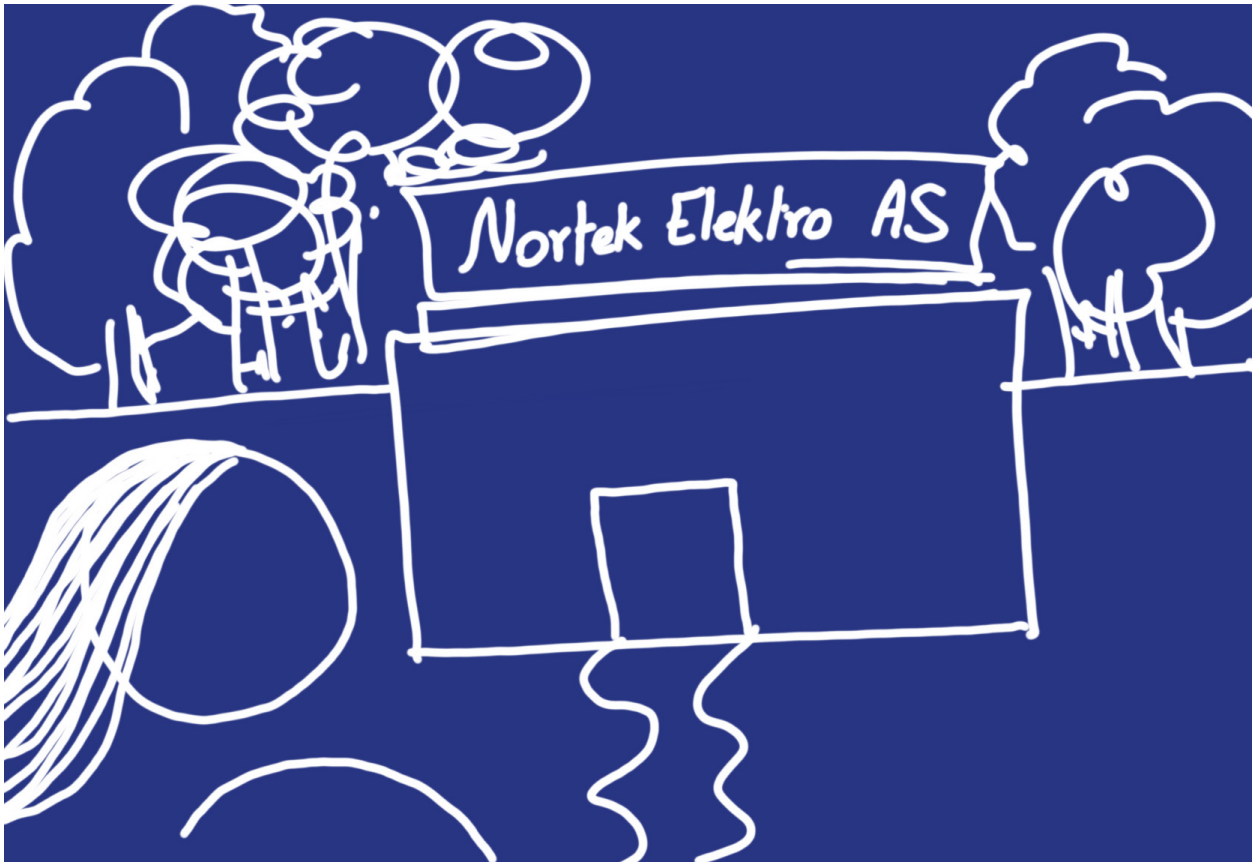


Figure 25. The materials of the future downlights



Interviews. 02

Magnus Hovd, **Electriacion-Nortek Elektro**

I have talked with Magnus from Nortek Elektro Åfjord. Magnus is an experienced electrician busy with mounting different LED lights such as downlights. Talking with him highlight several issues, he describes the product from different sides that I could never come to that by myself.

1. Can you tell me a short description of the process of mounting downlights?

   - First, we have a meeting with our customers here in the office, recommend to them the downlights that suit their houses and respond their matters. We carry the product into their houses and install it for them. In the installation process sometimes there are the iso safe boxes inside the ceiling (the non-flammable boxes to follow the regulations of Norway) in advance but sometimes, I will put them inside and make the hole by the drill. After the hole is done, I will connect the main cables to the driver and the other product and then to the downlight. I put the driver into the hole first and mount the downlight after that.

2. What are the iso safe standards?

   - According to the regulations in Norway, it is not allowed to put the downlight which is not iso safe directly in the isolations inside the ceiling. For this reason, we usually use the iso safe boxes and when it is not possible to use the box we must use the downlight that has the iso safe sign.

3. Which tools do you use for mounting and taking them out?

   - The most useful tool is a cable cutter to separate the plastic cover from the wire and connect it. Sometimes I use a cutter to make the hole clean and cut the extra material around that. And also drill for making the hole.
   - Some of the lighting products have a rectangular form, we can’t use the drill, instead, we should cut out the ceiling with a saw. I have to mention that it is time-consuming to cut out rectangles instead of circles. I also use a laser leveller to mount the downlights exactly in a straight line.

4. Which difficulties do you usually have with the downlights?

   - I can’t see any specific difficulty. I think the products that we are using are good and easy enough to mount. But sometimes the less space in the ceiling is a problem. It is

difficult to put the driver inside since there is less space for the hand to go inside and the cables are for the product. If I do the iso boxes myself it is easier for me and I will put the cables as near as possible.

5. Have you ever broken the downlight/ ceiling while installing the product?

- Sometimes it has some problems. Not breaking the ceiling but I have to be careful to not have any marks on the ceiling and mount them carefully. But taking the downlight out of the ceiling is more likely to break the ceiling. I think the weakest point of this product is the springs that are a sudden shock to the ceiling when you release them inside.

6. What do you think about the springs of the downlights? Do you think they are good enough?

- I mean, they are not the best they have their problems, but they keep the product tightly on the ceiling and easy to mount.

7. What do you think about the driver of the downlights? Have you mounted the products with an integrated driver?

- I have never installed that kind of product with an internal driver. The products that we are using have an external driver and it is easy to work with them. I keep the driver as far from the downlights as I can because I don't want the heating being produced by either driver or LED to influence each other and damage them faster.

8. But does the external driver need more time and effort? Would you prefer it even when you think the internal one is easier?

- Yes, I would prefer it more even when it takes more time. I would rather deliver the best quality to the customers.

9. Which type of downlight is more common in your company?

- We usually use the Junistar type from SG company. That has good quality and is easy to mount. It is reasonable to use this downlight. It is also flinking less light.

10. Which parts in the downlights make the most problems?

- I don't know which part is the most problematic, we usually have been asked by a customer to fix the light and we change the whole package and throw it away.

11. Have you ever been asked to repair the downlight?

- No, neither customers nor the company ever asks us to repair it. We only have to fix

the problem of the downlight for customers and I think it doesn't have any difference for them to repair the old one or to replace it, the result is important for them.

12. Do you have to add any other thing?

    - I want to add that, in the outdoor places next to the sea, the humidity and the salt will destroy the downlights and make dust. It would be nice to think about these conditions.

Kenneth Stjern, **CEO & former electrician- Nortek Elektro**

Talking with Kenneth, the CEO who is the link between customers and electricians, was a good idea. He is familiar with the taste of their customers due to regular meetings. And on the other hand, knows the electricians' concerns about the product and installation process. He used to be an electrician for years which gave him a comprehensive understanding of LED downlights. In this interview, I've skipped some of the questions to make more room for a discussion about circularity and the future of downlights.

1. What do you think about the most challenging part of mounting downlights?

    - I think that the most challenging part is that we have three products (driver, cable connector and LED downlight), it was much better if we have the driver and cable connector in one product, however, some companies are producing them in one place. And also electricians don't accept the downlights that required more time and effort for installing. The easier and faster the product is the more chance it has to survive in the professional market. The electricians are the fan of products that can be installed with no tools and very quick.

2. Which difficulties do you usually have with the downlights?

    - Several years ago the hole diameter was smaller than it is common now. It is therefore difficult to make the whole bigger while we have it in advance. We use such products that make it possible for us to fit them even in new holes or the previous ones. These products have an extra plastic ring to solve this problem easily.

3. What do you think about the springs of the downlights? Do you think they are good enough?

    - I think that these springs are good because when you want to take the downlight out

of the hole you can pull it strongly and do it. If we want to change them it should be possible to take them out easily. I also have seen some products that have the screws instead of the springs or the parts should be assembled separately, but this makes the process worst for the electricians.

4. What do you think about the driver of the downlights? Have you mounted the products with an integrated driver?

   - I don't think that it is a good opinion because of less space inside the ceiling and the regulations. The driver makes much heat and if you use it inside very close to the iso box the temperature may deform the box. It would come down in the middle part. When it comes down it pushes the downlight and the outer surface would become loose. Not tight enough and make a small gap between the downlight and ceiling. so maybe it is smart to keep the driver and downlight separate.

5. Which type of downlight is more common in your company?

   - Actually, we could have very options in the market, but we prefer to buy products from Norwegian companies such as SG and CTM Lyng since we can have our orders at the company faster. We can't wait for a long time for the shipment process.

6. So you never buy the products in advance and store them?

   - Not actually, in many cases, we order the products whenever we get the order from our customers. It is because every day the products are getting newer and developed. We want to have the latest version for our customers.

7. When it comes to selecting the products, is it the customers' opinion more about the type and brand or is it you that decide?

   - Customers usually ask us about the best option and brand. Of course, they have some expectations from their point of view, but it is us that make them willing to buy a product.

8. Which factors are important for you and which for customers?

   - For us, it is important that the product has good quality, last for a long time and satisfies our customers. We want products with fewer issues and a convenient mounting process. Customers usually are concerned with light colours, visible frame colours, reasonable prices and suitable for different parts of their buildings. When they get the guarantee or warranty from us, they are not concerned with the quality of components since we are

responsible for that issues.

9. Are the customers concerned with the smart functions? Such as syncing the lights with the app or changing the light colours?

   - These days is getting more popular to have all the things on the app and your phone. Some customers asking us about changing the lighting colour but I believe that in the feature we have more demands regarding these kinds of functions.

10. Do you find it important for the downlight to have the adjusting function?

    - Adjusting is very useful, especially in the gable ceilings. But I can see that today companies are producing most of the products with this function and focusing on 360 angles rotating. In my opinion, it is not that important to have the downlights being adjusted in every direction and 80% of the time it remains at the normal situation without adjusting, I suppose.

11. What do you think about circularity?

    - I think nowadays companies and people are becoming more aware of respecting the environment. However, if we produce a product which is following green thoughts such as sustainability and making the product out of ocean plastics it may not hundred per cent survive in today's market but I am sure that would become very papular in the future.

12. Do you have any other thoughts or opinions regarding this product?

    - I can see that in the market there are a huge number of downlights, for example, the same company is producing many downlights which are not very different from each other but are not the same. I can't understand the logic behind this since it makes the process more difficult for us. Because if the customer wants the same product that was purchased several years ago, we can't find that anymore in the market. And also it is against circularity if we want to replace one part of the product it is not possible to find the spare part in the market.

Continue Ideation and Sketching

This section introduces the more developed ideas with a focus on housing, integrated driver and mounting function (analysis concerning alternatives for springs).

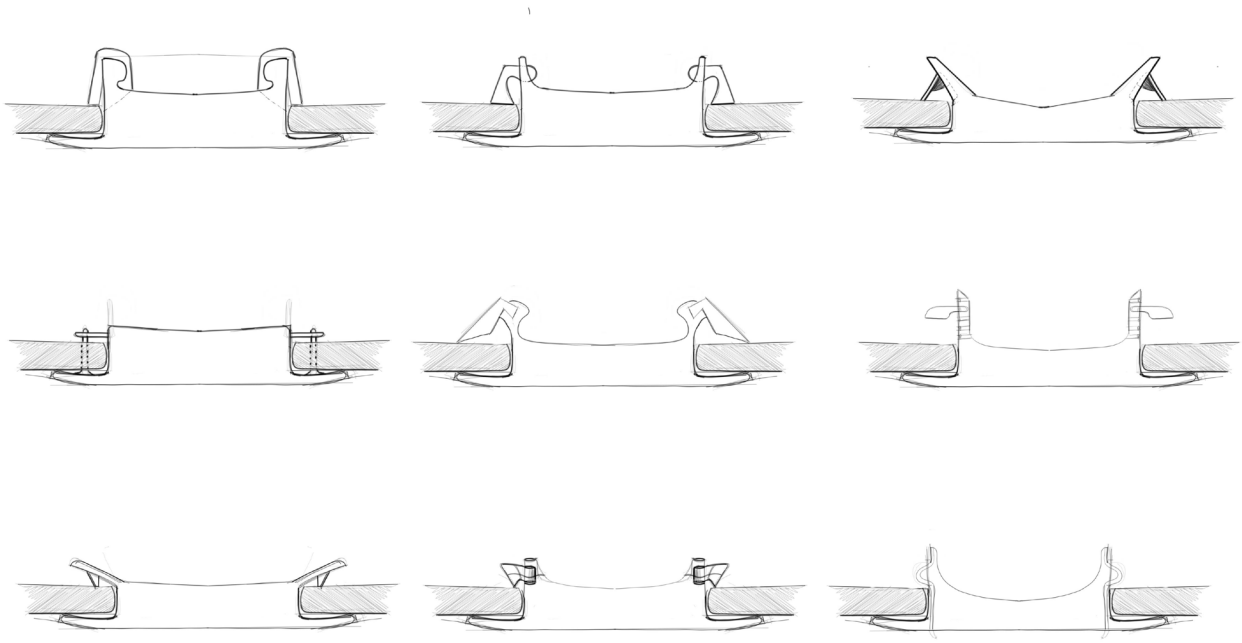


Figure 26. Design studies in springs functions.

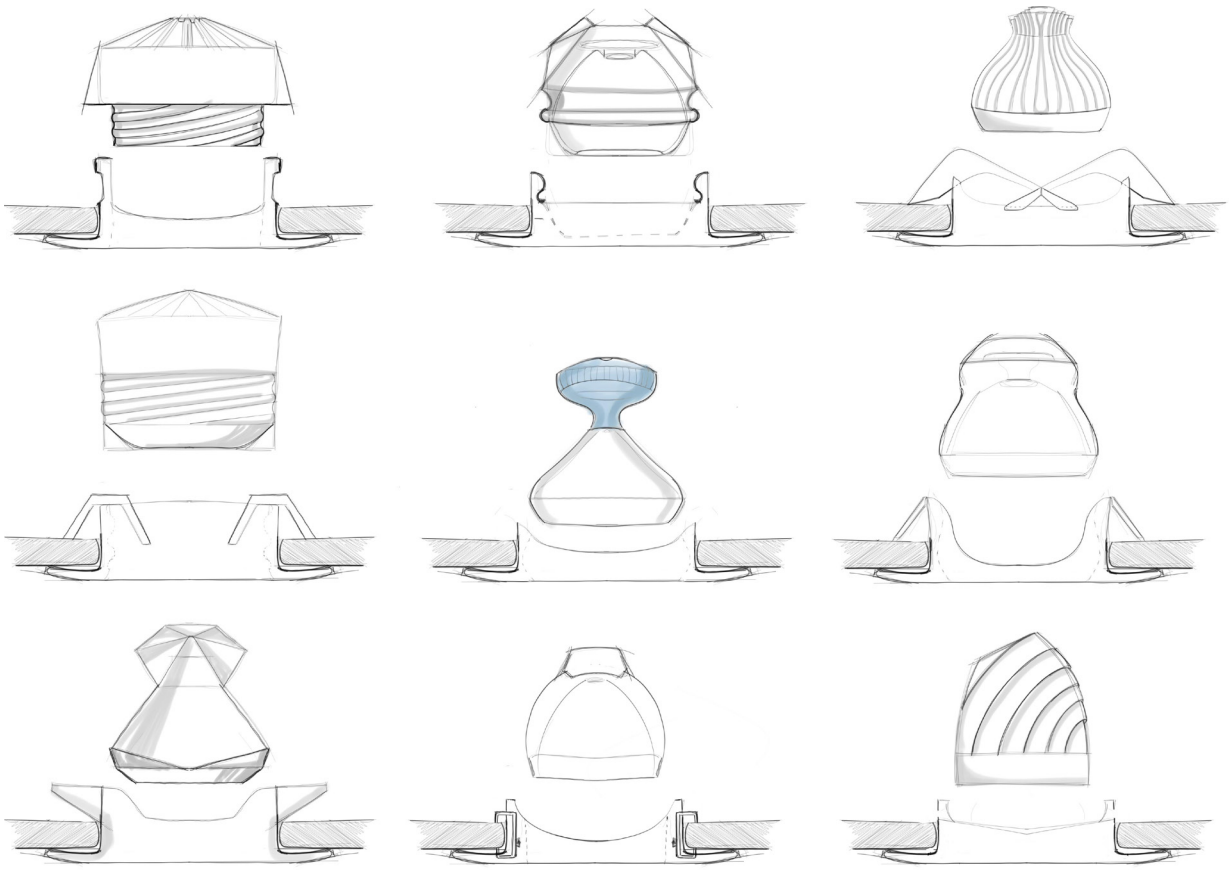


Figure 27. Design studies in housing with integrated driver.

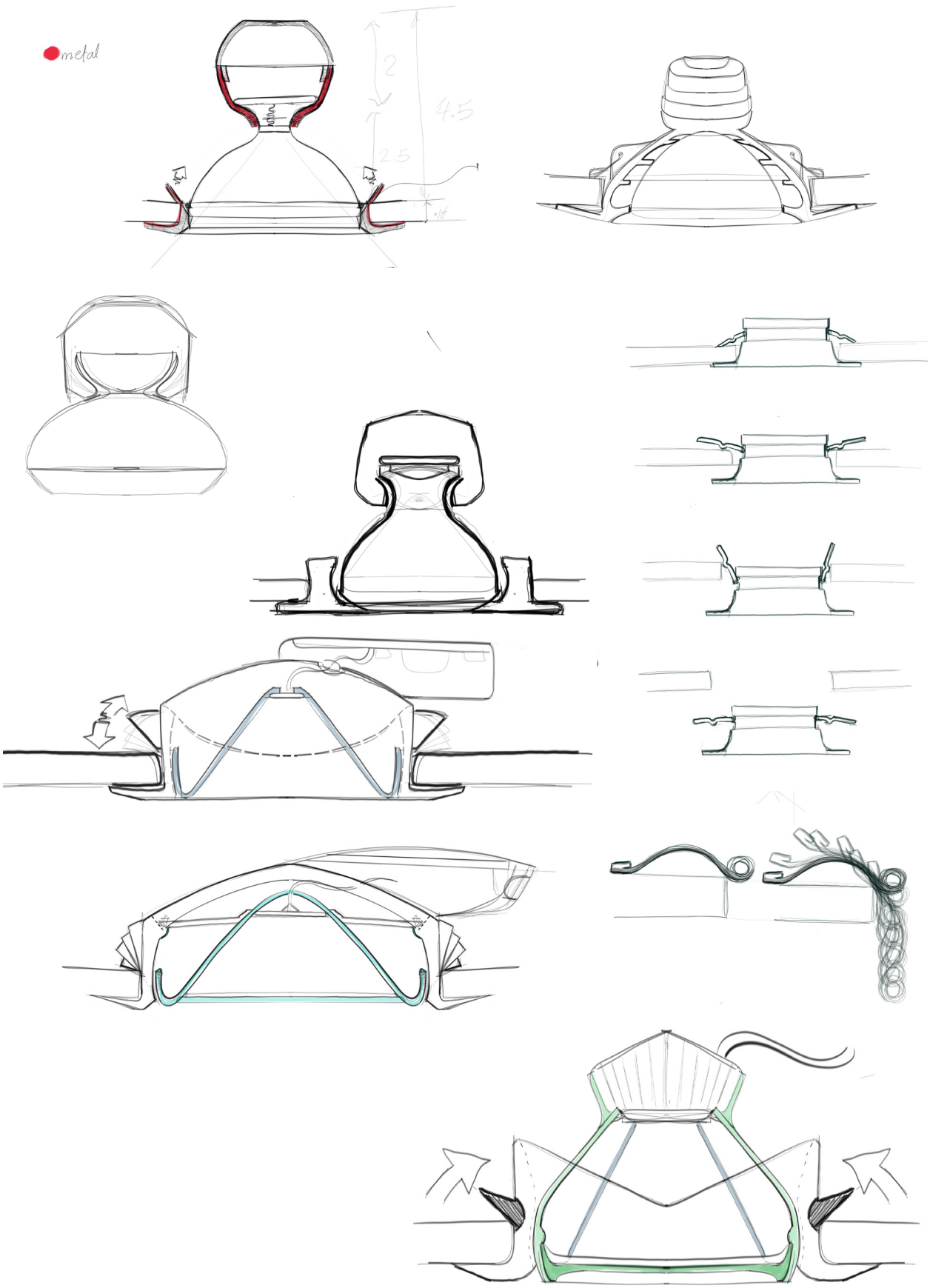


Figure 28. Sketching for the downlights ideas.

After several sketch practices for the springs alternative, I came up with the three main ideas. I've implemented the ideas in the 3d model software to see the overall view and evaluate them. I didn't use any specific evaluation method but instead attempted to test their function.

First Idea: In this concept, a metal ring has considered around the main body of the downlight. This ring is considered to provide a stronger surface that can hold the springs. It has two types of housings, one with external heat sink fins and another one with internal fins. The form of the housing is inspired by soda cans to influence the user about the recycled aluminium of downlight hosing.

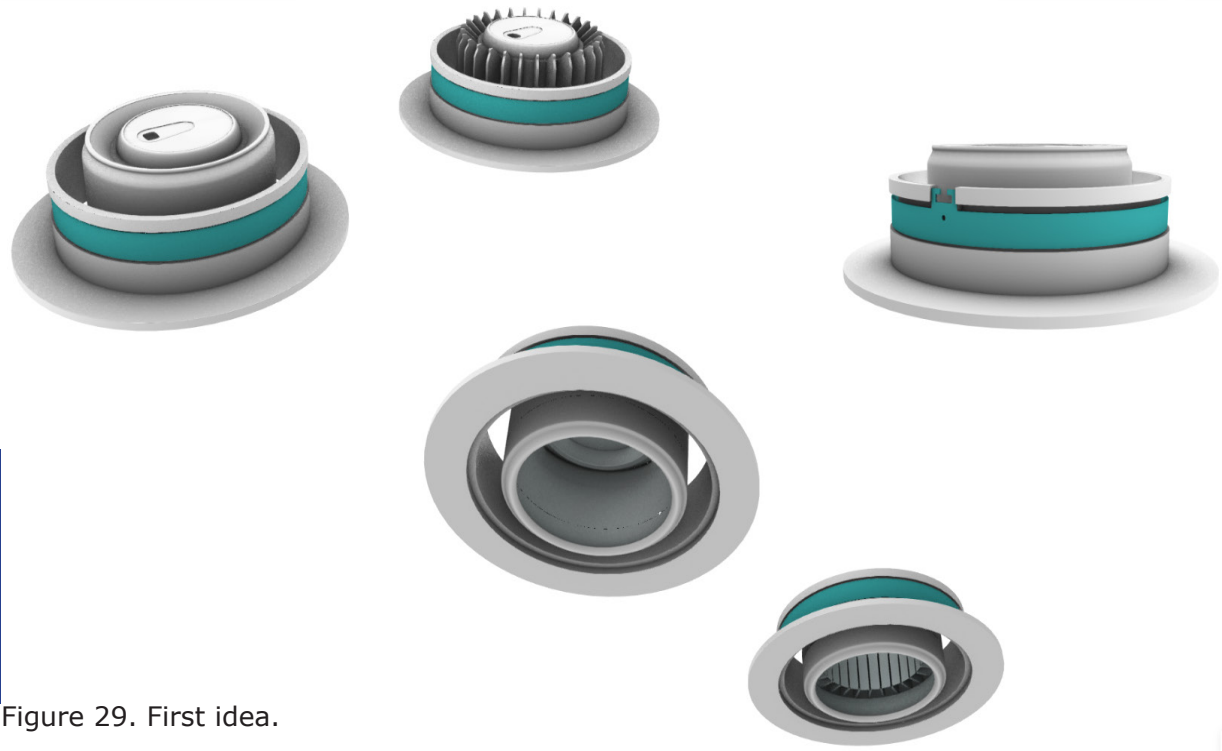


Figure 29. First idea.

Second Idea: This idea has been considered the other type of springs. As the illustration shows, these kinds of springs are like a flexible sheet metal that has been bent. The metal should be strong enough to keep the downlight tightly in the ceiling but at the same time easy for installing and uninstalling from the spot. For this idea, I provided a piece of metal and tried to bend it in the workshop. It was tricky to make the second bend and the result was unsuccessful experimentation. In the end, it was not appropriate to attach the metal part to the body. (I've tried to attach it to one of the existing plastic downlights) Becoming sure about the function needs a deep experiment while consulting with the technician in the workshop was not optimistic.

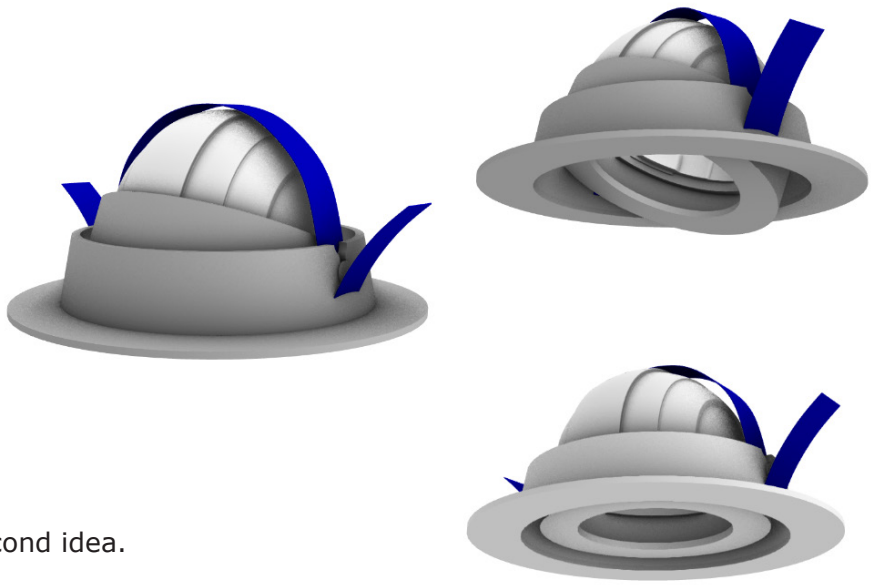


Figure 30. Second idea.

Third Idea: The last concept includes the existing springs for mounting function. It has a protective ring that controls the springs and gets them stuck. The springs are attached to a metal part and not the main body. The form of the housing is considered to be innovative. This idea seemed the most reasonable concept to me. So I've picked this idea as the one that I want to develop. The other concepts can be used for some of their details.

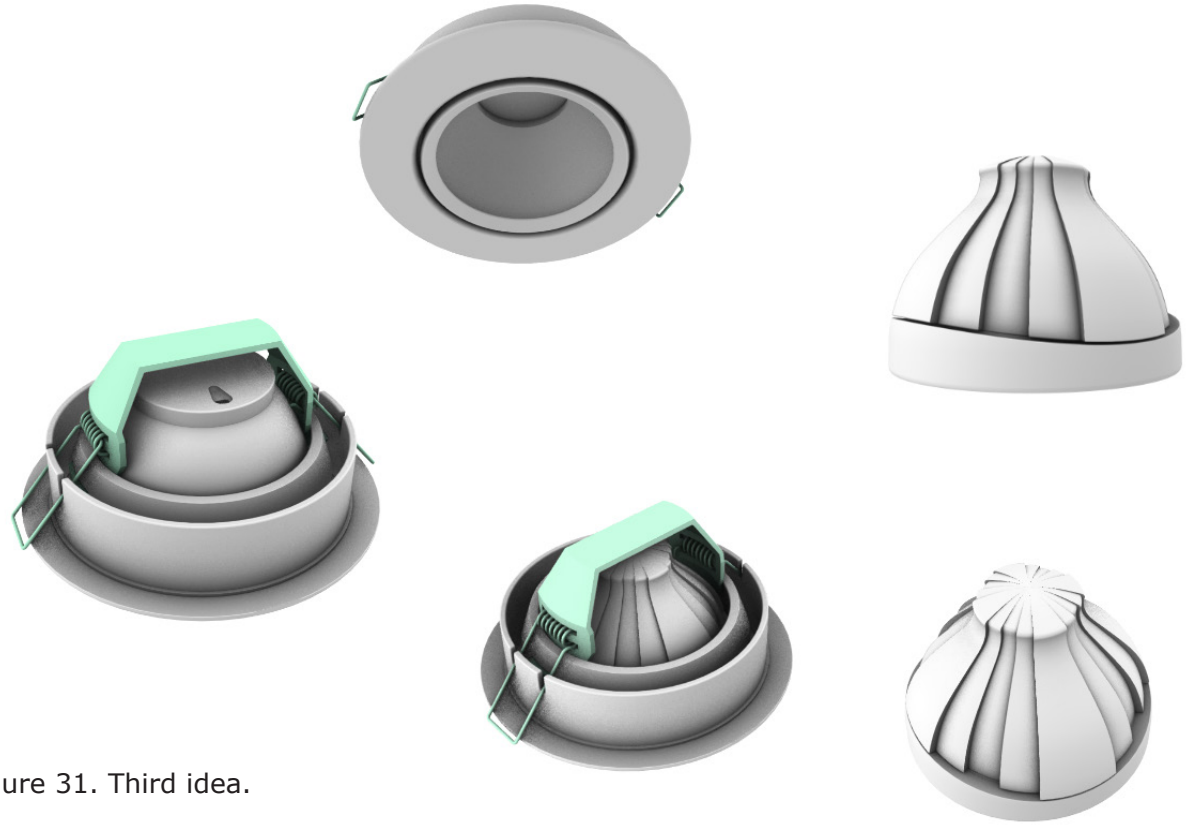


Figure 31. Third idea.

Standards

LED downlights such as every other industrial product require specific standards. The main concern with electrical products is fire safety.

There are two points when it comes to this notion; the electrical devices carrying the electric pulse that may lead to fire through the faulty electrical outlets, parts and outdated appliances. It is important to have a product with safer and more resistant components. An appropriate structure could prevent spreading fire and explosion inside the products. Another type of fire safety is when the fire happens in a place where there are installed downlights in the ceiling or walls. In this case, the downlights must perform as obstacles preventing the flames pass the ceiling. In Norway specifically, the buildings are made of wood and could immediately burn. For this reason, there are strict regulations regarding the production and installation of the downlights.

Iso safe or Insulation-proof Downlights: Some of the downlights are permitted to mount directly inside the insulation and some of them are not. The downlights that are not insulation-proof should be mounted inside the iso-safe boxes. All of the downlights have a symbol on the labels highlighting this feature.

Figure 32. One type of Iso Safe downlight box from SG company.

To achieve the exact information and regulations, I have read through the “Lovdata” website section; Regulations on Electrical Equipment. The regulations that were more concerned with downlight products have been extracted and presented briefly.

1. General terms and conditions

1.1. Information that is necessary to know to ensure that the electrical equipment is used without danger for the purpose for which it was made, must be stated on the electrical equipment, or if this is not possible, in an accompanying document.

1.2. The electrical equipment, together with its parts, must be designed so that it can be assembled and connected correctly and safely.

1.3. The electrical equipment must be designed and manufactured in such a way that protects against the dangers described in nos. 2 and 3 is ensured, provided that the equipment is used for the purpose for which it is made and that it is properly maintained.

2. Protection against hazards that may be due to the electrical equipment.

The electrical equipment must be designed and manufactured in accordance with No. 1 so that,

2.1. Persons and domestic animals are properly protected against the risk of physical injury or other damage that may be caused by direct or indirect contact.

2.2. Temperatures, arcs or radiation which may cause danger may not occur.

2.3. Persons, livestock and property are adequately protected against hazards of a non-electrical nature which, from experience, are due to the electrical equipment.

2.4. The equipment's insulation is adapted to the conditions that can be foreseen.

3. Protection against hazards that may be caused by external influences on the electrical equipment.

The electrical equipment must be designed and manufactured in accordance with No.1 so that the electrical equipment

3.1. Meets the expected mechanical requirements, so that persons, livestock and property are not exposed to danger.

3.2. Can withstand non-mechanical influences under the environmental conditions the equipment is expected to use, so that people, livestock and property are not exposed to danger.

3.3. Does not expose persons, livestock and property to the risk of congestion and other foreseeable defects.

Apart from regulations and safety issues, it is important to know what are the standard dimensions for downlights. These standards come from the limitations of mounting spots (ceiling & wall), the preferences of the users for its visual aspects and to correspond with the tools and equipment that professionalises used to mount. I have asked the project manager, Vidar, to see if there are any documents for the specific measurements of the product and found that the standards are the collection of market research, user demand and standard tools. For example, most of the common downlights have 76mm or 83mm diameter since this is the standard size of the hole saw. So the company demands specific dimensions in some parts. When it comes to the marketing goals it is an opportunity to keep the product as small as possible, but I also should consider that this compact value doesn't influence product characteristics and that technical features remain intact.

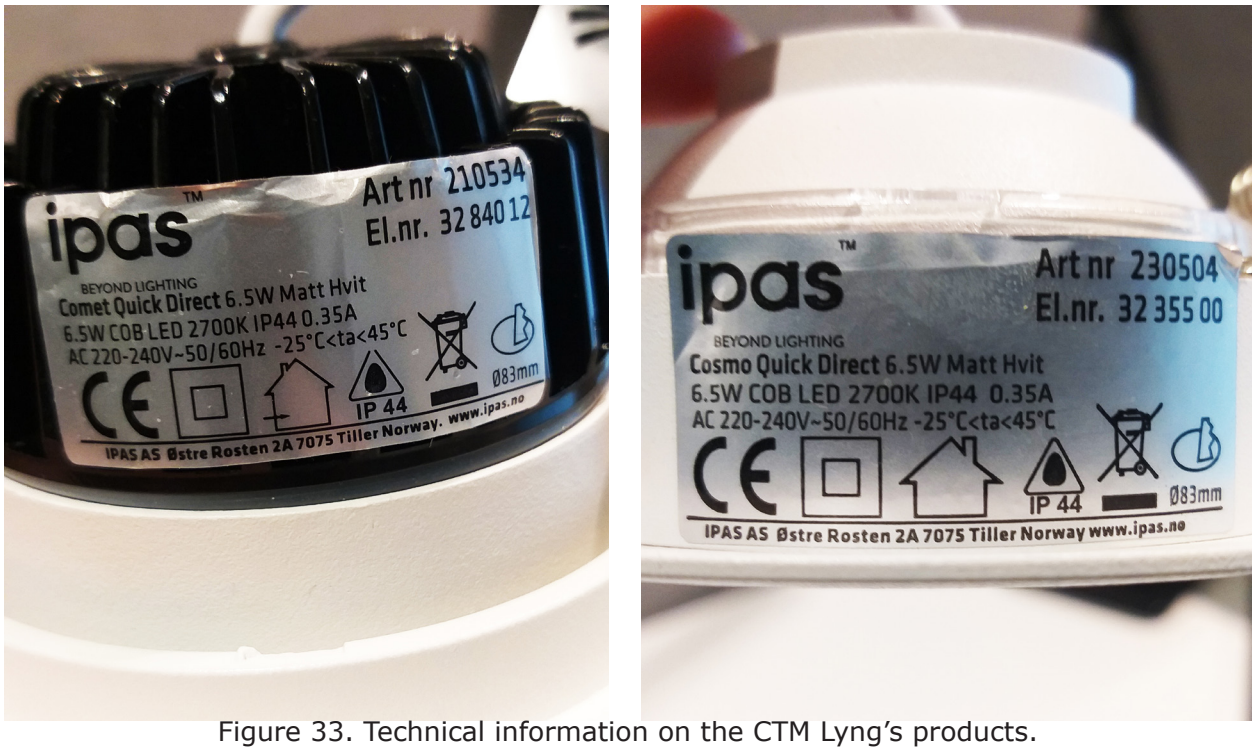


Figure 33. Technical information on the CTM Lyng's products.

What is Ingress Progression Code?

Ingress Progression (IP) is the basic way of expressing how effectively the light is insulated from outside influences. The IP rating of an electrical device indicates whether the outer casing will protect the working parts from water or solid object infiltration. (Elesi, 2019)

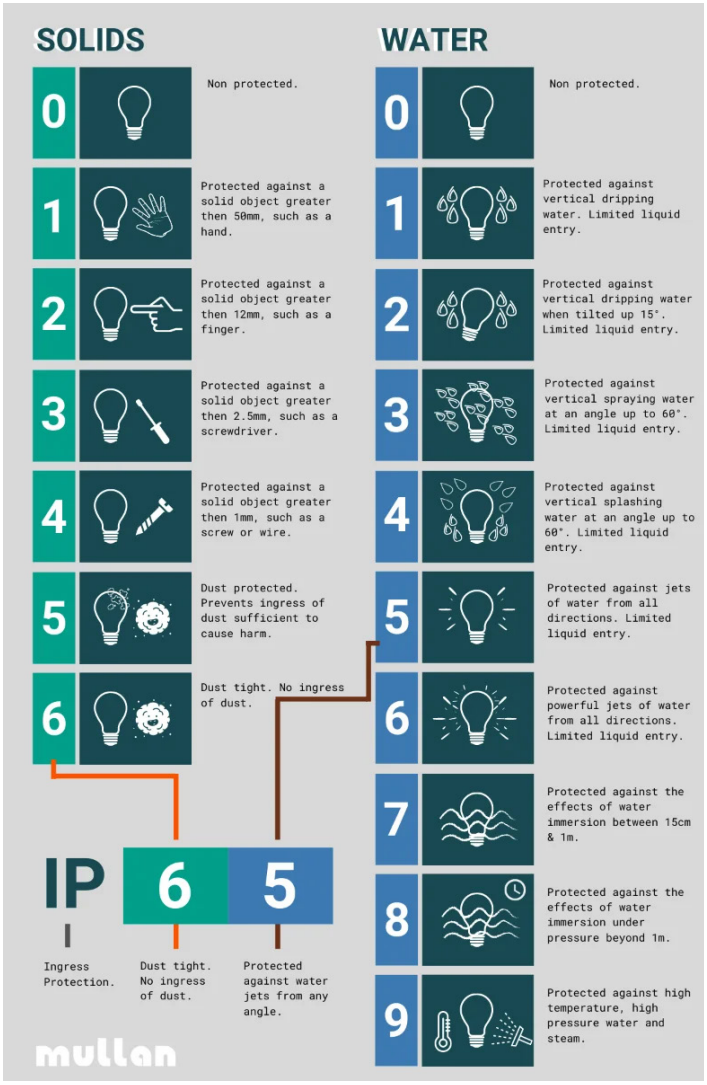


Figure 34. IP Rating Visual Support Chart (Mccarey, 2020)

Benchmarking the Existing Downlights

Together with the company, we have ordered some current downlights in the market. The purpose was to take them apart and to see the design decisions, components, materials and details of the actual products.

Sample no.01

- Brand: ALUSSO
- Manufacturer: ALUX
- Dimensions: 95 x 95 x 50 mm; 647 Grams
- Material: Aluminium, Polycarbonate
- Special features: Colour temperature adjustable, 100%-10% smooth dimming, Energy-saving, Long lifespan, Integrated design, IP44 waterproof, Easy installation
- Average life: 30 000 Hours
- Operating voltage: AC 220-240 Volts
- Colour temperature: 3000K- 4000K-5700K adjustable
- Price: 75 kr

Figure 35. Alusso downlight, Amazon.

Findings:

The purpose of purchasing this product was the material and the integrated driver. The product contains the main body, one PCB board, the aluminium reflective housing, a shaded glass, springs, one piece of paper, screws, an opening cap, and LEDs on the board. It was difficult to disassemble the product and in the description, I found that this is not a repairable product. One interesting point is that there are compact components in this lighting and it is made as simple as possible. It is obvious that the product benefits as fewer parts as it could be which is the aim of my project as well, but the point is that this is a fixed light and it is not possible to adjust the angle. Moving parts require more components. Below there is a table of the pros and cons of this product.

Pros	Cons
Simple production Fewer parts Integrated driver Adjustable colour temperature Lightweight High light beam angle Cheap Fewer glare	Traditional Springs Unrepairable Non-recyclable plastic Overheating Non-adjustable angle

I also checked the ranking of this product on the Amazon website and figured out several reviews. So I found some critical issues with the product. Such as overheating which leads to damaging the shade glass and reducing the lighting lifespan. Another issue that several customers refer to was poor shipment method and non-suitable packaging that leads to damage physically and technically in the product.

Figure 36. Alusso downlight customers' reviews, Amazon.

Sample no.02

- Brand: SOLO
- Manufacturer:
- Dimensions: 75 x 110 x 147 mm; 340.19 Grams
- Material: Aluminium, steel and polycarbonate
- Special features: Colour temperature adjustable, 3 fascias finishes, wattage switchable (8W & 10W).
- Average life: 50 000 Hours
- Operating voltage: 240 Volts
- Colour temperature: 3000K- 4000K- 6000K adjustable
- Price: 250 kr

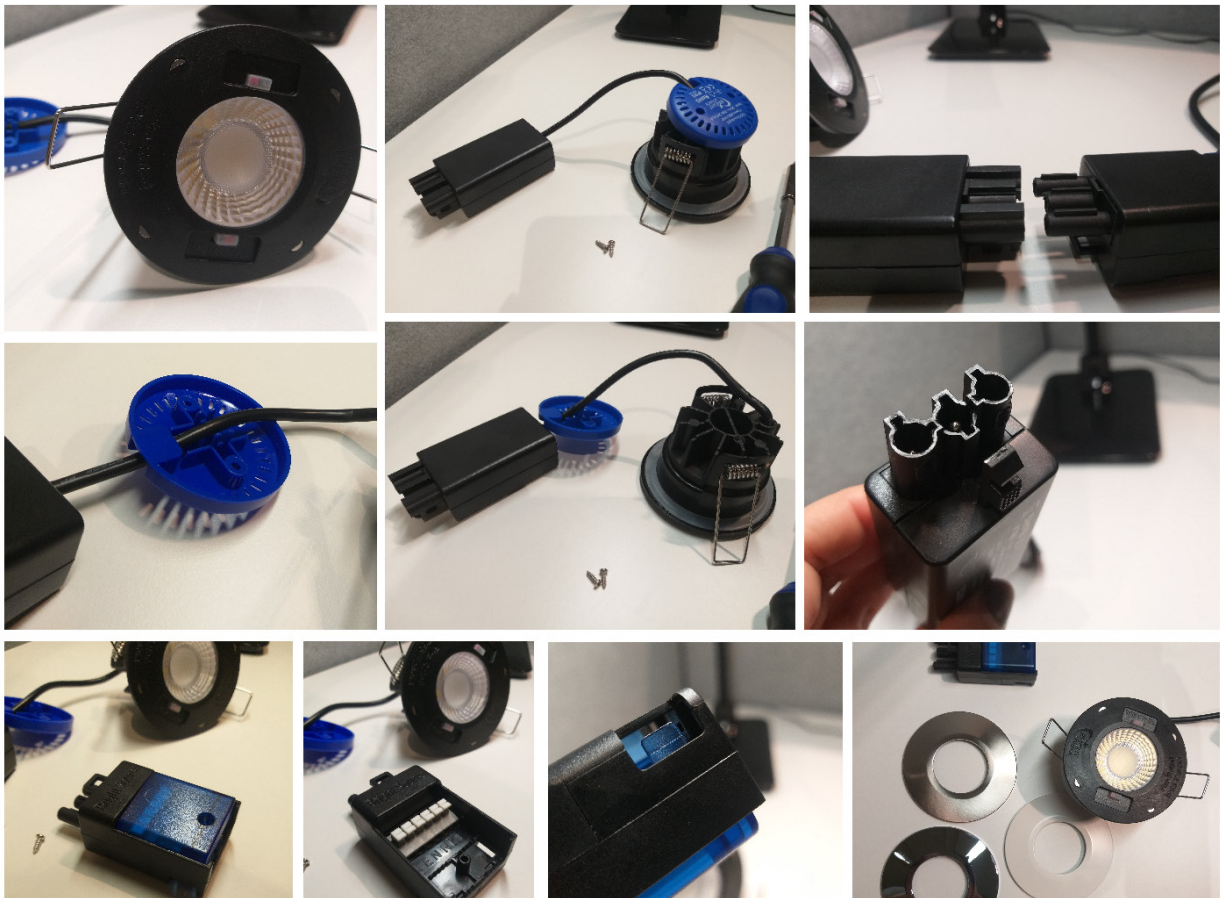


Figure 37. Solo downlight.

Findings:

It is impossible to disassemble the product. The only separable part is the plastic cover on the top that holds the wire in its place. The other parts are fixed and pressed strongly by the production process and it is not possible to take them apart. This product is also the fixed light in which it is not possible to adjust the beam light angle. The electric driver and the connector are two separate parts so the electricians have three parts to install in the ceiling, however, the driver has a fixed wire with a downlight. The plug and play connector helps to have an easier and faster connecting process.

Pros	Cons
Adjustable colour temperature Changeable fascia Switchable wattage	Traditional Springs Unrepairable Non-recyclable plastic Non-adjustable angle Merge different materials together Separated driver and cable connector No plastic buckles for springs

Coming to reviews on Amazon, customers are complaining that the lifespan of the product is less than it says. The product is not possible to be repaired therefore they have to pay for a short time product, throwing the whole package away and buying a new one. The only satisfaction about this downlight is its ability to change the fascia that making it suitable for each place. It is an important fact that this product is completely against circularity. But the problem which remains is that the magnet function in some cases leads to noises when it is in close contact with electricity.

Sample no.03

- Brand: SG
- Dimensions: 50 x 94 x 48 mm; 0.39 / 0.325 Grams
- Material: Aluminium, tempered glass
- Special features: Adjustable light beam angle
- Average life: 50 000 Hours
- Wattage: 8W
- Beam angle: 42°
- Operating voltage: 220- 240 Volts
- Colour temperature: 2700K

Findings:

I have disassembled the downlight and it was not an easy process to go through. Firstly I have tried to figure out how it is possible to disassemble and which screws are the main screws. While disassembling, I changed my screwdriver several times since there was not one specific size for all of the screws. It was time-consuming to use different screwdrivers. The downlight is designed with a complex system because the adjustable mechanism is complex. The springs are stronger than other products. Due to experiments and interviews, it is unnecessary to have these strong springs.

Pros	Cons
360° Adjustable Unpainted aluminium inside the product Long life-span	Traditional Springs Difficult to repair Merge different materials together (glass and aluminium melted together) Separated driver and cable connector No plastic buckles for springs Screws with different sizes Complicated design Having 16 screws

I didn’t find the online reviews for this product and it is selling to the professional market. The source of feedback about this downlight is my interviews with the Nortek Elektro. They said that this is the most common downlight that they are using. The biggest problem in their opinion was to have a driver and cable connector in two different products. It makes the mounting process longer. The springs also were not satisfying for them.

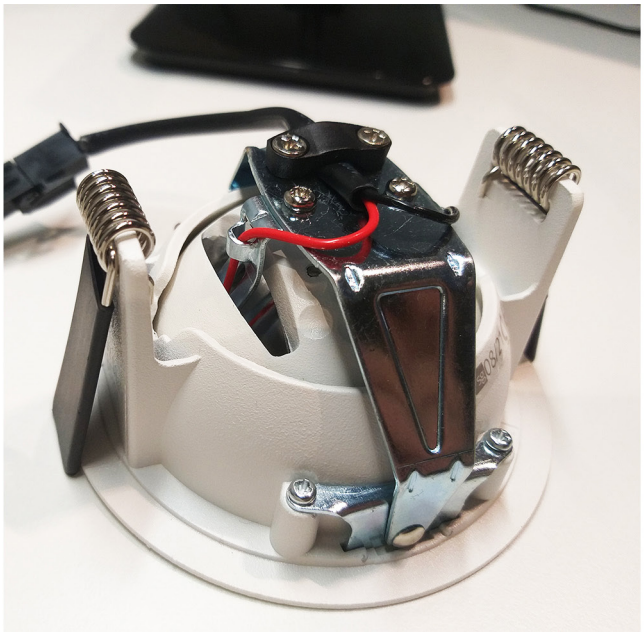
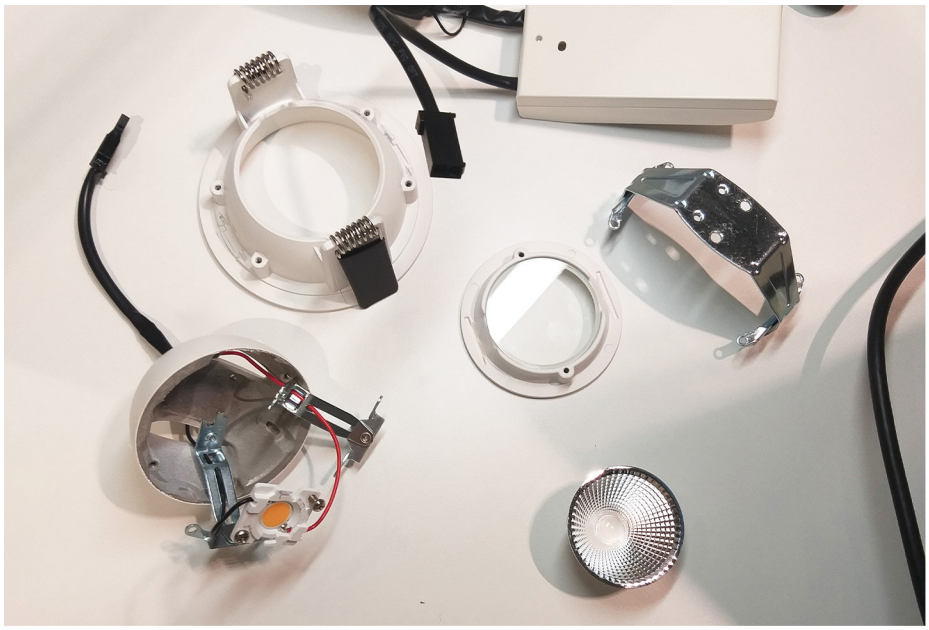
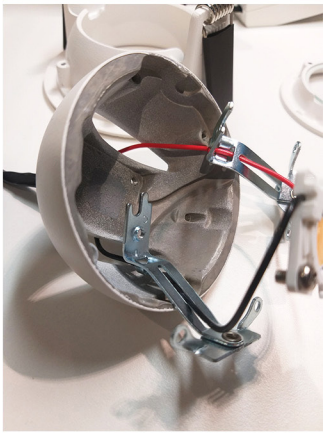
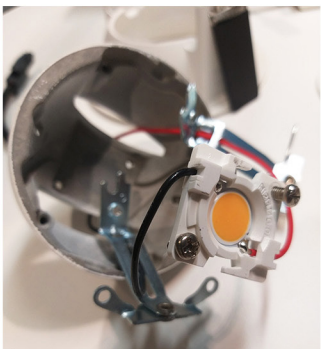




Figure 38. SG downlight.










Traditional Springs

The discovery demonstrated that most of the existing downlights and the products with similar mounting processes mount by the kind of springs that I have named 'traditional springs' in this thesis.

The reason for using the term 'traditional' is that these springs are in use for many years, probably they don't have better alternatives yet.

Several downlights benefited from another type of screws that are not as easy to mount as traditional ones. For example, in one type the screws are used with vertical springs that need to be adjusted by the screwdriver and require more time for mounting. In this product also the outer frame should be attached in addition to the product, more steps for installation.

Observations and interviews showed electricians blame these springs that are easy to mount but difficult to take the downlight out from the spot and also very time-consuming for installation.

Figure 39. The glamox D70 with the specific springs type.

Project experiments and Youtube videos have proven that springs become stronger while pulling the downlights from the lower level (outside of the hole) and placing them at a 90° angle with the ceiling.

After the springs get in a proper angle to get out, they would land powerfully, mostly hitting the fingers ,such as a mousetrap, or destroying the hole and surrounding area.

However these traditional springs are not perfect, they are the best option yet. I have tried many ideas and thoughts to find a better solution and replace them during the whole process. By far I didn't achieve a better solution due to many challenges and factors that should be considered.

In conclusion, we can design a tool or consider a part in the product to lock the springs or reduce their risky function.

HeatSink

Heat sinks are general cooling systems in electric products such as LED lighting (Park, Jang, Yook & Lee, 2016). These parts are crucial in these products since they provide the path for heat to transfer from the LED light source to outside elements (Scully, 2019).

LEDs should have the proper thermal contact with the heat sink, it means, if the LEDs are loosely suspended above the heat sink it has less thermal conductivity and more heat. It is important to attach the LEDs to the heat sink with something that has a low thermal resistance. The most useful method to have this feature is using thermal epoxy. It is better to have a maximum surface and the minimum thickness in the epoxy rather than a small surface with a thick layer. (Lenk, 2011)

According an experiment by Hussaini A., the Simscale website has been used to simulate the thermal conductivity in three different types of heat sinks. The illustrations (Figure 40) shows that the heat sink with plate-fin is providing better sinking compared to the inline and staggered pin fin heat sink (Hussaini, 2015). So the more efficient type of heat sink is the plate-fin heat sink where the fins are directly attached to a thicker layer of aluminium and the part is in direct contact with LED. the recent product of the company also is designed according to this feature.

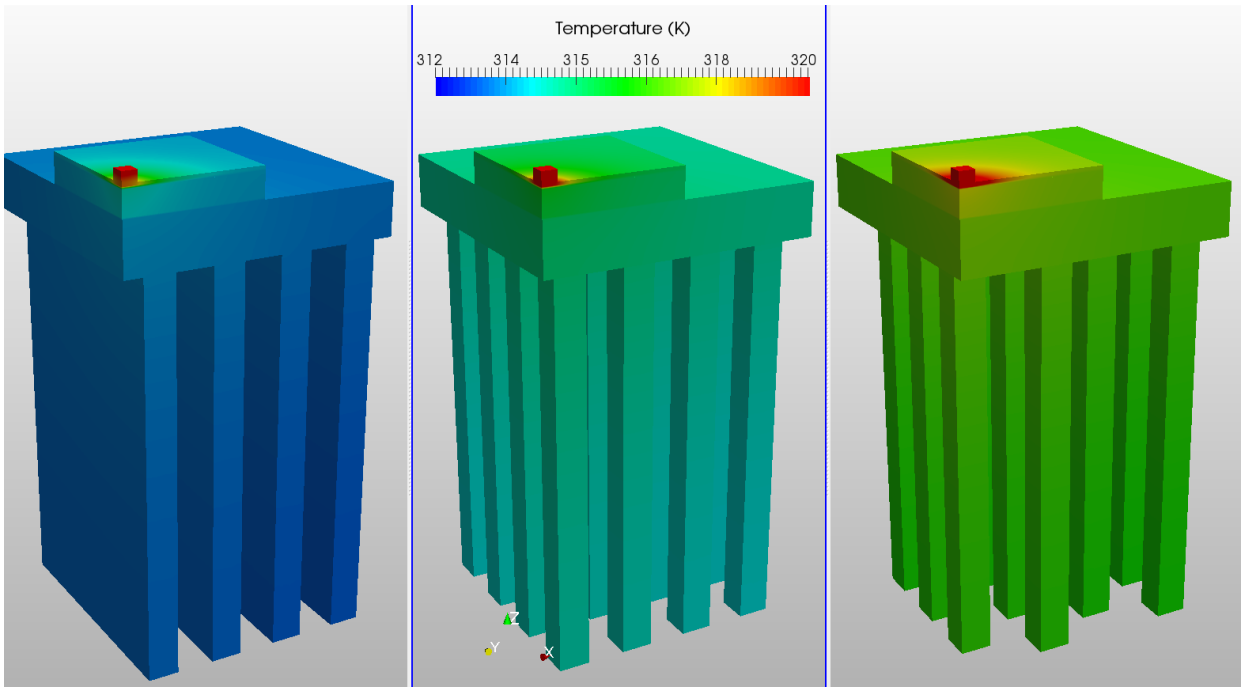


Figure 40. Thermal simulation experiment by Hussaini, 2015.

Even though designing heat sinks are technical and above this thesis, I found it worth noting some parts of 'New Frontiers for Design of Interior Lighting Products' in this section.

"Thermal conductivity is what distinguishes one heatsink from another in terms of material. Copper (400 W/mK), Aluminum (237 W/mK), Brass (100 W/mK), Steel (100 W/mK), Stainless Steel (15 W/mK), Alumina Ceramic (20–30 W/mK), and Aluminum Nitride Ceramic (170–200 W/mK) are just a few examples. Despite their lower heat conductivity, thermo-conductive polymers such as Polypropylene (PP), Polypropylene Sulfide (PPS), Polyamide (PA), or Polycarbonate (PC) are commonly utilised in consumer lighting. Fillers (ceramic, metals, charcoal, graphite, etc.) are typically added to these polymers. These solutions are more convenient since they are less expensive, lighter, and easier to use." (Siniscalco, 2021)

"The form of the heatsink must let as much air as possible to lap the dissipating surfaces; the higher the heatsink-air exchange area, the better the thermal performance. The shapes of heatsinks can vary greatly. They are generally determined by the geometry of the lighting fixture and the heatsink's typical orientation in its regular working position."(Siniscalco, 2021)

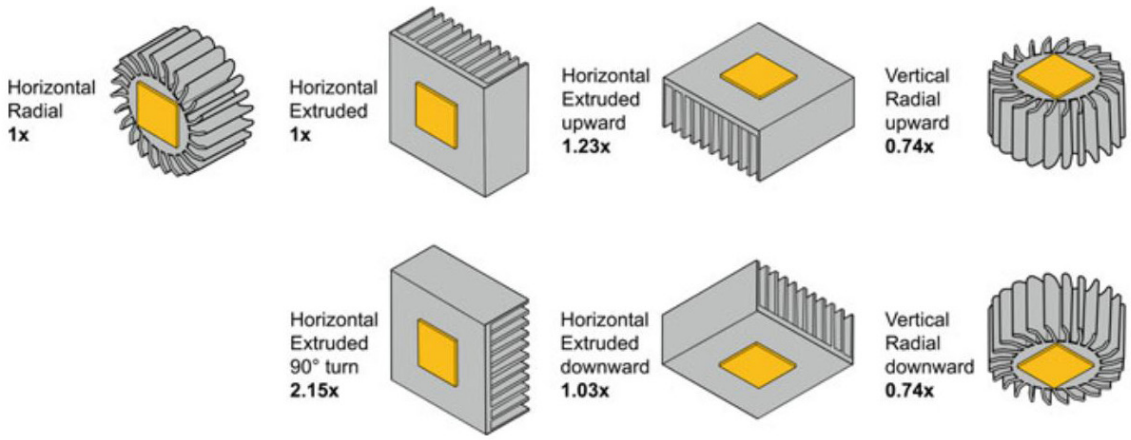


Figure 41. The thermal resistance of different heatsinks as a function of their operating position.

"Heatsinks are manufactured using a variety of methods, including extrusion, solid machining, folding fin, bonded fin, moulding, and die casting. Each process imparts distinct properties to the product, affecting its capacity to transmit heat. For example, an extruded aluminium alloy can have a conductivity of up to 200 W/mK, but a die-cast aluminium alloy can only have a conductivity of 150 W/mK."(Siniscalco, 2021)

Conclusion of Define Phase

According to the achieved information from the 'Define' phase, there are several important issues to consider in designing the LED downlight. This conclusion is set due to the context of the project, having a circular economy and following Norwegian standards and regulations.
Current components, standards, materials and LED technology don't let the product benefit from an integrated driver.

Springs are too strong, therefore, it is significant to improve the attaching part by the use of suitable material or a specific design solution.
The new design should focus on the professional market, benefit them and make them willing to use this product.

According to the interviews, it is difficult to remove the downlight from the ceiling, which might result in finger injuries and false ceiling breaking. The project demands an easy method for doing so in order to facilitate the repair and reuse procedure. This is one of the project's issues that might be addressed by the product itself or by providing a specific tool for the job. Adjusting function is something important for some places such as gable ceilings but it is not necessary to adjust it by 360°. Once the electrician sets the downlight angle, it remains like that for many years. This 360° function usually results in more parts and different types of materials in the final product.

Some of the products have a physical button for adjusting colour temperature but it is not something that the consumers could do easily. Considering the height of ceilings and difficulties to reach the light, it is not reasonable to adjust the light during consumption. On the other hand, instead of adding extra parts such as buttons and making the product complicated the user can purchase the desired temperature or change it by mobile app.

Develop

The development was in process during the whole project, but what I pointed out here specifically, is when the achievement in discovering and defining parts joins with the ideas, resulting in narrowing down the project boundaries. This phase makes the previous concepts more accurate and will lead to the final concept at the end.

In this phase, I have thought about the product details and performed a back and forth process between different requirements, design briefs, standards and exact measurements while having the concepts on one hand and the actual samples of the market on the other hand. This stage has been started by 3D modelling and 3D printing of the product to figure out which problems have to be addressed and which fit well. It is also important to test the ideas by having physical prototypes, analysing the strengths and weaknesses of each part and trying to conclude them as convenient as possible.

Some of the specific parts of the development phase are research about the materials and production methods. I would open the section with the discussions I had concerning injection moulding and material.

Production Method

I have visited the IV Group AS in Leksvik to observe the injection moulding process in person. During the visit, Sten Anders Lian guided me through important issues in the injection moulding process, I also asked him about the important factors that I should consider in the design which lead to a better quality of products. In the conversation, he mentioned that this circularity approach is quite new for them and they've never produced a part from recycled material before.

First, I went to the maintenance section, where they were repairing and manufacturing tools and cavities. I questioned the cost for each cavity and discovered it depends on design specifics. For example, a product that requires more electrodes for the manufacturing process is more complex and requires more time and cost. There are a lot of principles in the injection moulding process that I have to implement in my product.

Visiting the injection moulding provided me with a better grasp of the process and helped me understand how each design decision influences the whole production process. It indicated the importance of design in my mind by seeing how each simple line that I draw in my sketches means something specific in the production process. So, from concept to production, numerous stages must be taken, and various adjustments must be made in accordance with current manufacturing technology.

In the development, I will consider basic injection moulding guidelines and not every detail because of the thesis limitations. These guidelines have sufficient professional resources to be referred to that I don't want to bring all of them into the thesis. Below there are several injection moulding principles to be considered.

- Add the draft to the vertical walls.
- Uniform wall thickness
- Shell Out Thick Sections
- Avoid Undercuts
- Round Edges

- Adding Text or Logos
- Thread Features
- Snap-fit Joints
- Living Hinges
- Surface Finish

During my visit, I got introduced to the 2K machine, a two-layer injection machine. The machine makes one plastic part with two different layers with two injecting shots. It means two types of plastic are melted and combined together with the machine leading to the different features colour, and softness on each side. This is something useful in many products and I have to have it in mind for concept development.

Material & Specification

I spoke with Vincent Gartiser, a material engineer who formerly worked for Nidar and now runs a small firm manufacturing handmade products out of recycled plastic.
First, I discovered his interview on Trondheim Renholdsverk's website, which was fascinating. So I planned a meeting with him to talk about plastic and recycling, which I couldn't afford on my own and needed someone to inquire about. The conversation lasted around 40 minutes and was a constructive conversation regarding various aspects of plastics.

Figure 42. Vincent workshop, Trondheim Renholdsverk,2020.

1. What do you think about plastic composites? Are they recyclable?

- Biocomposites such as the mixture of wood and plastic are recyclable but if you have the right partners close the loops with them. If you just want to throw it by the user, it is not recommended and it would end up with more environmental issues. You have to have the partners and make the platform for users to return the product to you and you recycle and reuse it.

2. Which kinds of plastics do you recommend for the product?

- I think the most common plastic for electrical products is PP. The Electrolux company in Sweden is making their products such as vacuum cleaners out of recycled materials. You should have a look at their products. PET is not as appropriate as PP because PP has better strength and lasts for a longer time.

But anyway, you can have your specific requirements for your product and consult them with the material engineer and it is possible to make a plastic structure that has the requirements and at the same time the recycling option.

3. I want my product to be easy for the recycling process, which factors in your opinion are the most important factors?

- The most important factor is the disassembling option. If you are using different materials it should be possible to disassemble it easily. If you want the user to do it you should make it easy to disassemble. In this case, it does not work well if you use screws or other joins. The materials also should have clear marks that show the type of material.

4. I saw in your products that you have colourful finishing surfaces. How is it possible to have these kinds of finish parts? Isn't the finished recycled plastic gray colour?

- One of the good things about the manual process of recycling plastic is the kinds of visual features that you can achieve. But it is also possible to have it in mass production. There are some products in the sports shops such as XXL and Sport OBS that are selling plastic products for skiing and camping cups that have this finishing feature and are produced on the mass production scale.

5. What are the special properties of recycled plastics?

- When you melt the plastic and recycle it, all of the mechanical features such as strength decrease. The more times you try to recycle it the more mechanical features

you lose because you are breaking the polymer's structure and building them again. So when you are designing a product with recycled plastic, you should consider having more thickness than you have virgin plastic. It is a good option to see the other products made out of recycled plastic and make a comparison about their thickness. But anyway with the help of an expert person, you can decide better about these kinds of features. There is a company called Norner, they are the ones that make the samples and test them for you and help you with these challenges.

6. What do you think about painting the plastic for a better finishing surface?

   - Whether you paint the plastic chemically or by adding additives to the material, you are making the recycling process more complicated. In my opinion, you have to define the best finishing surface that you want for your customers and consider that having a circular product is maybe more important to have a shiny finishing surface. The best finishing surface is different for me and you or your company. You have to decide about it and evaluate it.

7. Do we have recyclable non-flammable plastic?

   - It is possible to add non-flammable additives to the material and still recycle it. It needs the exact science and knowledge to design the specific plastic.

8. What do you think about polycarbonate? Is it recyclable?

   - Polycarbonate is also a recyclable material. I have worked for Nidar chocolate company for eleven years and when I think about polycarbonate, I have them in mind. It depends on the quality and quantity of the products your company wants to produce. I know that polycarbonate in low quantities in some companies is just considered waste material, however, it has the possibility of being reused again. If you are thinking about local suppliers just need to look carefully at the companies that can provide you with these kinds of waste materials, and have another partner who changes it into the appropriate material and then produces it. It is possible but it requires accurate planning.

9. Thanks, Vincent for your time, and do you have any other things to add to this interview?

   - I suggest you have a look at Norner, Aage Vestergaard Larsen A/S and swerec websites. They are beneficial for your projects in terms of plastics and recycling.

Good luck with your project!

Figure 43. 3D printer, CTM Lyng.

Concept Development

3D Modelling: To make the sketches clear, I have started to 3D model the ideas from the middle of the define phase and continue until the final steps. There is a back and forth process between ideation, developing ideas and 3D modelling. I used Solidworks to create the files and exported them as a final.STL file for 3D printing. The 3D modelling procedure was done in different steps. I discovered the bugs and experimented with the concepts at each level, then 3D modelled them again with new changes.

Rendering: In this section, I didn't find it crucial to have high-quality illustrations by rendering since the purpose was to develop the concept and experiment with it. So I've used the render view in 3D software and made the screenshots whenever it was necessary to illustrate parts.

Prototyping: I have used the 3D printers at CTM Lyng and the department to have samples. Each time I have done the prototyping it got more accurate and more advanced in comparison with the last time. Springs, LED light, cables and other components have been borrowed from the existing products.

Concept Development

Concepts and analysis

Concept No.01: The first concept was the experiment of the initial ideas, so it didn't cover details except the one that I wanted to test. The concept consisted of four parts. the adjusting function is considered 360° and the springs are the traditional ones. The cutout hole must be 83mm but it is also possible to fit the light in the 76 mm hole. The parts and details have been described by illustrations of the concept and drawings that clarify which changes should I perform in each part.

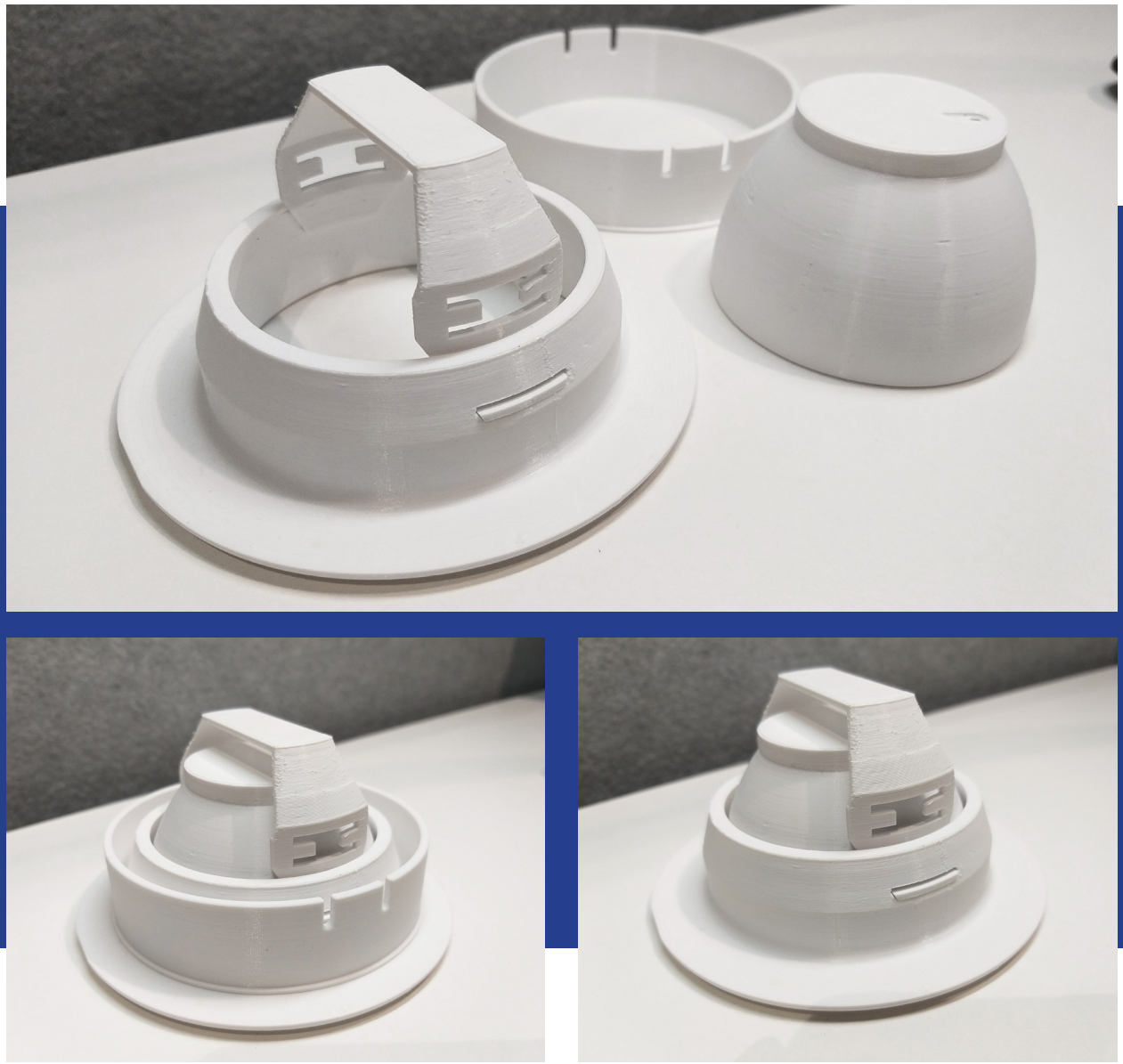


Figure 44. Concept No.1

The outer ring: This is the most visible part with certain unique characteristics in this concept. The ring itself has a circle shape but it has two cutting edges. It is not easy to recognize it by the general look but for the electricians who are aware of this function, it is a sign. The sign indicates that it is safe to keep the fingers on these points since the sprints will be landed in the opposite direction. According to interviews and observation, one of the problems that lead to injuring fingers by springs is that it is difficult to see where the springs land.

Figure 45. Concept No.1

This part is organising the mainframe for the adjusting part. It is therefore important to have a shape that makes it possible to rotate the inner part.

For the next outer ring, I should:

- Reduce the height of the outer ring.v
- Change the attachment type from cutting to snaps.
- Add space for a washer.
- Change the form of the curve.

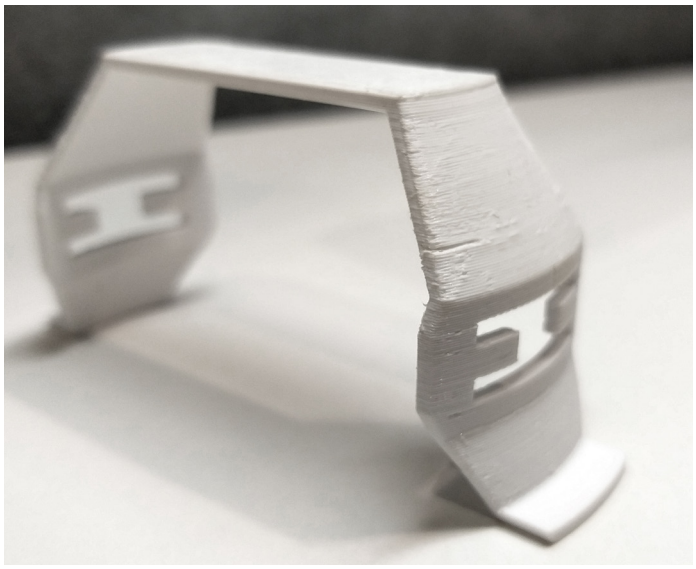
Figure 46. Concept No.1 exploded view

The springs holder: To keep the springs in the right direction and to avoid breaking the plastic parts, I have considered a metal part to be assembled on the outer ring and hold the springs. I have printed the metal part with the plastic material to test the aesthetics and the function. Due to reducing the number of parts, I have considered this metal as the holder of the adjustable part instead of using another part to hold it.

Figure 47. Concept No.1 springs holder

The changes for the spring holder

- Change the attaching part to snaps.
- Make a bigger hole for the springs to fit well.
- Increase the width.



The protective ring: This is the additional ring that must be placed together at the same time as the downlight. This ring is slightly larger, with an 83 mm diameter. The purpose of developing this component is to manage the springs. When the electrician is installing the product, he or she should stock the springs inside the ring and install the downlight in the ceiling. When it comes to removing the downlight, the procedure is the same. The outer part has a larger edge, about 84mm, which helps with positioning outside of the hole and will be covered by the outer frame. Another reason for having this section is that it allows the springs to release slowly, preventing the false ceiling from being broken.

Figure 48. Concept No.1 protective ring

The changes for the protective ring:

- Increase the surface that is out of the ceiling hole.
- Add some extra parts inside the ring to tighten it with the inner part.
- Think about an idea to keep the ring in the ceiling.
- Make a small angle on the walls.

The Aluminium housing: However, I have printed this housing out of plastic, it should make of recycled aluminium in the final product. The housing should have the heat sink surfaces (inside or outside) and it is important to open and close it for maintenance purposes. But I didn't make these details for this concept to save time and start with the more important features which need development. I have considered a cutting part that is for the electricity cable.

Changes for the housing:

- Decrease the height.
- Add fins (fins forms should be appropriate for the reflective cup).
- Change the curve form into a better curve.
- Think about the idea of having it in two parts.
- Increase the size of the hole for the wire.
-

Figure 49. Concept No.1 housing

Conclusion:

The concept has made lots of problems obvious and it is not functional enough. I've made all the aforementioned changes and modelled another concept.

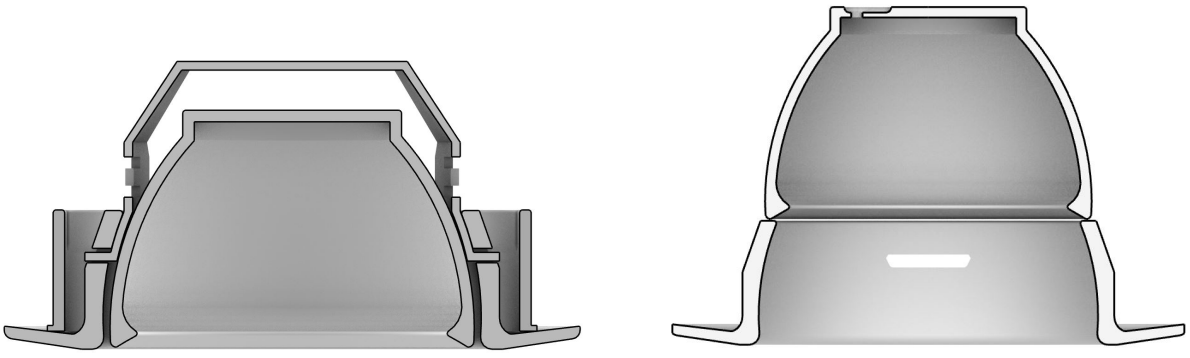


Figure 50. Concept No.1 housing

Concept No.02: Following the development process, I created the second idea by adjusting some features of the first concept in order to improve it and solve the problems. I've also tried to experiment with innovative ideas that came to me during the process. Because it is detailed, this concept has more pieces. The technical characteristics and approach are as the previous model. The measurements were inspired by the company's product (cosmos), but some minor modifications were made, and there are still requests to improve this concept and make it more developed for manufacturing.

Figure 51. Concept No.2

The changes for the outer ring:

- According to Frank's opinion, we could have an outer ring with a smaller surface to save material. So the next model should have a smaller diameter.
- Change the forms of snaps since they are not strong enough.
- Add the screw part to fasten the springs and also to make it impossible for the final user to repair.
- Think about some parts to place the protective ring in the right position.
- Add a small angle to the walls to make some gap between the ring and the cutout hole in the ceiling.
- The washer: I've considered a plastic ring for placing between the outer frame and housing (for better adjusting), but it has been concluded that it is not necessary to have it. The two parts are made of plastic and keeping the washer between them isn't needed. I'll remove this part in the next concept.
- It is not possible to rotate the adjustable part inside the ring, the next model should address this problem.
- I have to design an outer ring with the same dimensions but a fixed function.

Figure 53. Concept No.2 outer ring

Figure 54. Concept No.2 exploded view

The changes for the springs' holder:

- Think about the rotational part.
- Adding a screw hole on them.
- Improve the form for a better fitting of springs.
- The part dimension for attaching the springs doesn't fit the springs.
- The parts don't stick together well. The joint should have a better form.

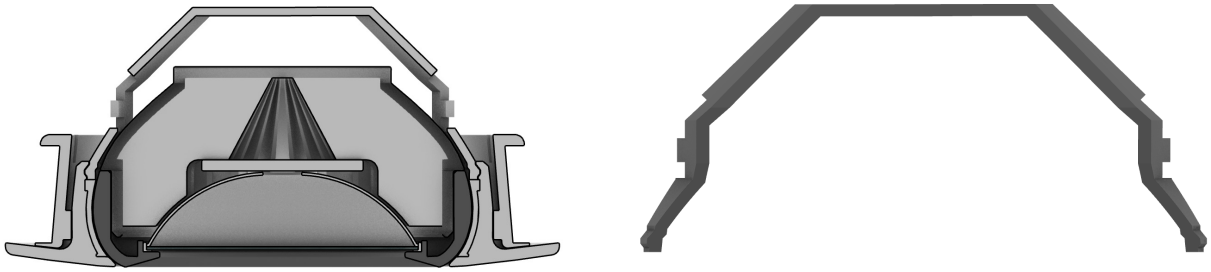


Figure 55. Concept No.2 springs' holder

The changes for the protective ring:

- Make the cutting parts bigger for placing the springs easier.
- Remove the protruding edge, since it is not functional and it makes the process even more difficult.

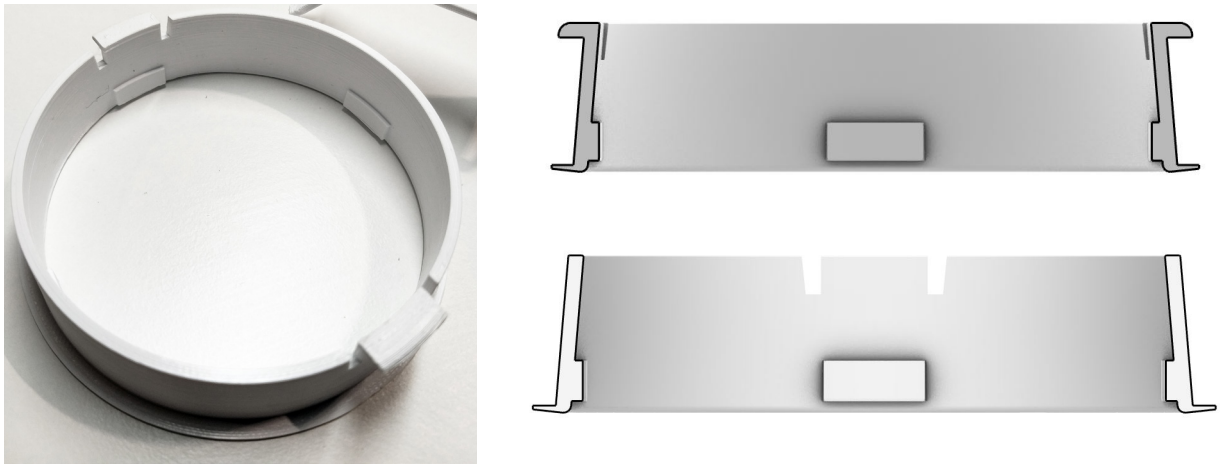


Figure 56. Concept No.2 protective ring

Housing: In this concept, the housing includes two parts. One part is the aluminium housing, holding the cable and LED chip, and the other is the plastic part that holds glass, washer and reflective cup and coordinates with the aluminium housing and other parts.

Figure 57. Concept No.2 housing

The changes for the housing:

- Make the thickness of the heat sink fins equal all over the part.
- Think about a way to keep the wire tightly in place to keep the product safe.
- The diameter of the part doesn't match the glass and washer of the current downlight. Need to be changed.
- According to "Practical Lighting Design with LEDs" by Ron & Carol Lenk, if the LEDs are suspended above the heat sink, they won't work properly. So it is necessary to attach the LED chip to the aluminium surface with the thermally conductive adhesives. (Lenk, 2011) For this reason, I have to consider a cylinder core in the heat sink with appropriate features. The part should be redesigned completely.
- After adding the aluminium to the core part, I should think about the mounting of the LED board on it. Think about how to skip the screws.
- The curve form of the housing doesn't respond to rotating it.
- The fins in the heat sink are thick, should be thinner. Also, the number of fins is too much. The research on heat sink shows that having a lot of fins lead to the fewer air between them and it is not the best for transferring the heat.

Design the LED board/ holder: For the next model, I should design a LED holder that could be mounted well in the housing. All of the current products have this part attached to the housing by screws and glue. I want to skip the screws and think about another mounting function because the screws need more time for the disassembly and adding the extra parts to the product. The board should be fitted well to the LED chip and reflective cup.

Concept No.03: The result of this concept was more satisfactory to me than previous examples. The adjustable mechanism works well. The fixed part design with the same dimensions as the adjustable part was interesting for the company. But still, some issues need to be addressed, which I have explained later for each part specifically.

Figure 58. Concept No.3

The changes for the outer ring:

- The outer edge is too thin and fragile. It doesn't have enough grip because of the thickness.
- The thin edge of the inner ring is not necessary and it should be removed.
- The thickness in some parts is much, must take it into consideration.
- The fixed outer ring is good but it has some of the same problems as part 2 of the housing and normal outer ring. Have to change it in accordance with the other changes.

The changes for the protective ring:

- The cutting parts still are small and difficult to place the spring exactly in them so make them even bigger.
- There is no need to have four extra parts inside the ring skip them and make them two.
- Modify it according to the other parts.

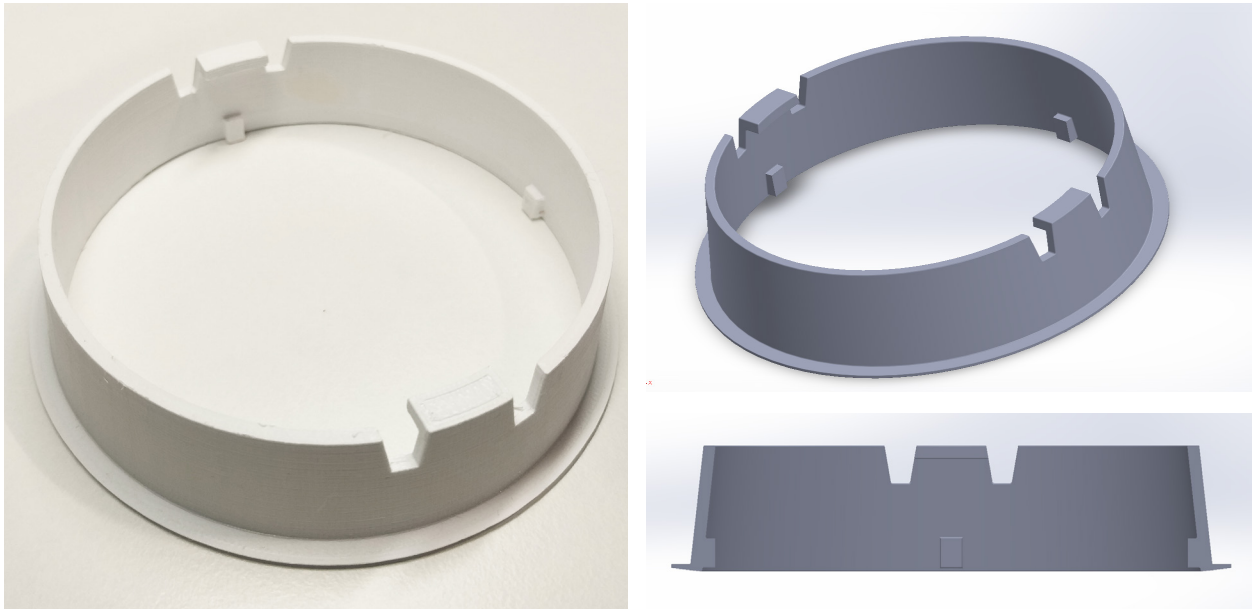


Figure 59. Concept No.3 protective ring

The changes for the springs' holder:

- The holes for screws should be half of the part thickness so there wouldn't be any scratching from the screws on the rotational part.

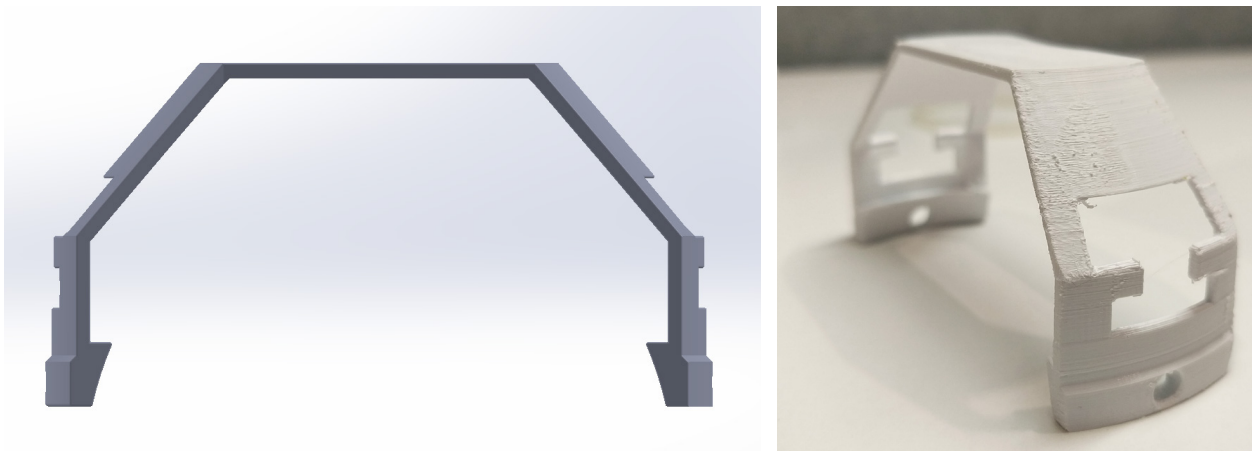


Figure 60. Concept No.3 springs' holder

The changes for the housing part 1 (heatsink)

- The number of fins is too much (14 pieces) and they are thin, 1mm. It is better to have fewer numbers but more practical. I have to change the thickness to 1.5mm and limit the number of them to 12 pieces.
- The considered mechanism for mounting the led holder to the heat sink is not good, have to redesign it.
- There should be considered some free spaces for wires.

The changes for housing part 2

- In this model, I have added an extra ring inside to extend the touching surface between parts 1 and 2. But it is not working well and makes the production process more complicated so I have to remove it.
- The surface where the glass is placed on the edge should be increased in width.
- The height of the small wall inside where the glass and reflective cup are placed should be increased.

Figure 61. Concept No.3 housing

The LED board/ holder: because of the changes in the other parts the led holder of the company's product is not useful for the concept. So I have designed a new one according to LED dimensions. To mount this board on the heatsink, I decided to place small pins on the board and create matching spaces on the heatsink. But it has the problem for assembling and disassembling process. Kasia told me that it is not a good way of attaching because the part is too thin and vulnerable and would break easily. For the next model, some changes should be implemented.

- The function of mounting to the heatsink should be changed.
- The thickness should be increased.
- There should be a consideration for the appropriate tolerance between led and pins, it is too tight now.
- A new reflective cup according to the new concept should be designed and set with the led board.

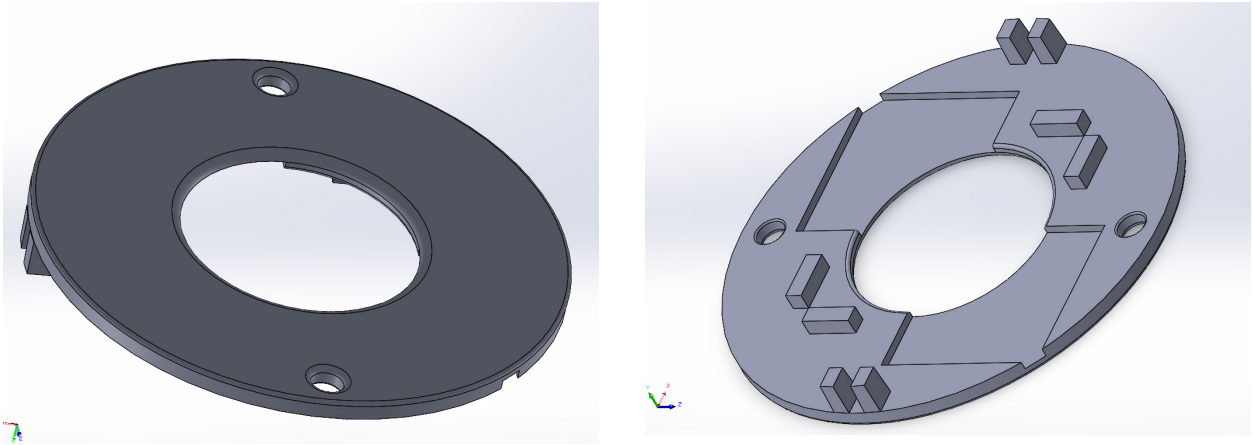


Figure 62. Concept No.3 LED holder

The fixed outer ring: This part is developed in accordance with the characteristics of the outer ring and housing part 2. It largely has the same issues as the mentioned parts.

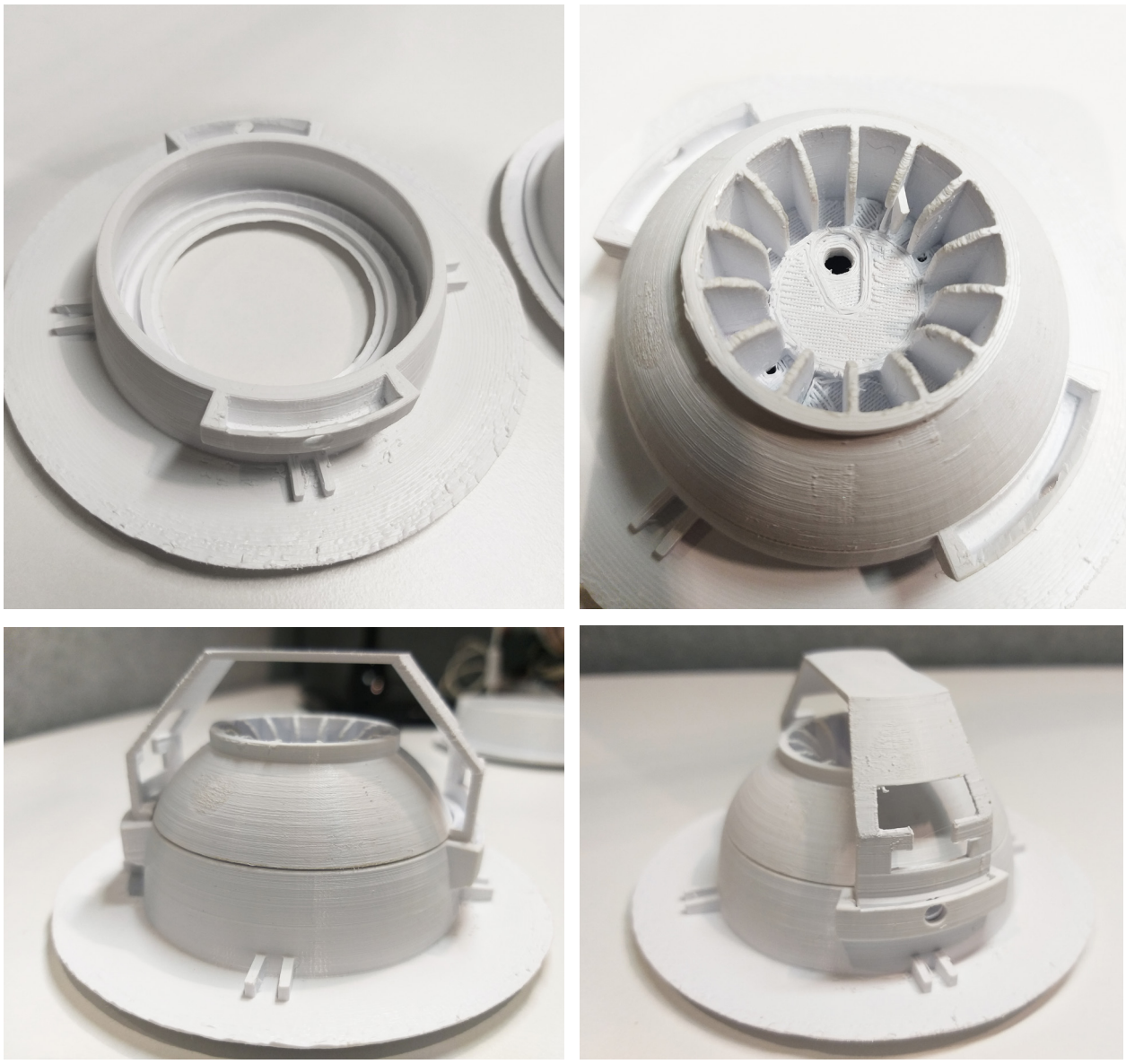


Figure 63. Concept No.3 fixed outer ring

Concept No.04: This concept is the final experiment for the thesis, and the next one should have all the improvements as the final product. Prototyping helped me solve many problems and greatly improved the concept. There are parts to this concept that are good and do not need to be changed, therefore I only mentioned the changes that have to be considered for parts in this section. I have shown this concept to the injection moulding company for plastic parts and I have implemented their ideas to a large extent in the final product. I also consulted with Leksvik Industrimekanikk for the metal part which made me realize many strengths and weaknesses of the product.

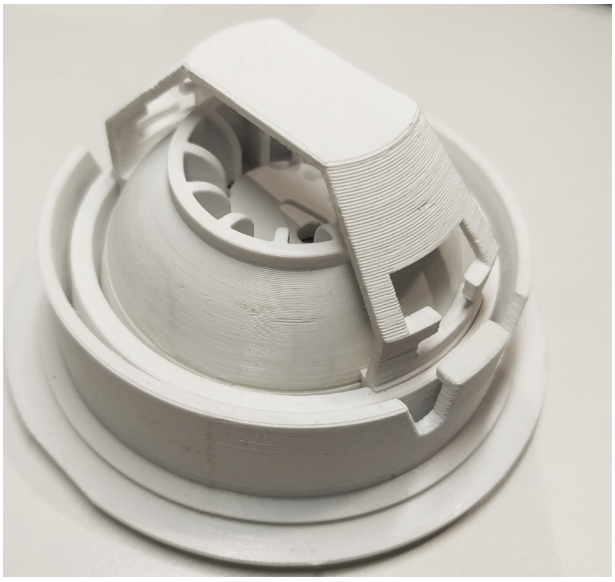


Figure 64. Concept No.4

The feedback from the injection moulding company and Kasia

- There are some undercut problems in the prototype, one in part 2 of housing. It is possible to produce it with the collapse injection moulding method but it gets more expensive, so it's better to make it straight. The other undercut is on the fixed outer ring it needs redesigning.
- The walls should have a 1° or 2° angle.
- The thickness of the outer edges should not be more than the previous levels because it makes it harder for the molten plastic to flow and increases the probability of the piece disorders.
- The thicknesses seem good.
- The outer ring maybe gets some sink marks because of the circle form but it also depends on the finishing quality.
- The fillets should not be less than 0.2 mm for preventing sink marks. (It has been considered in the model)

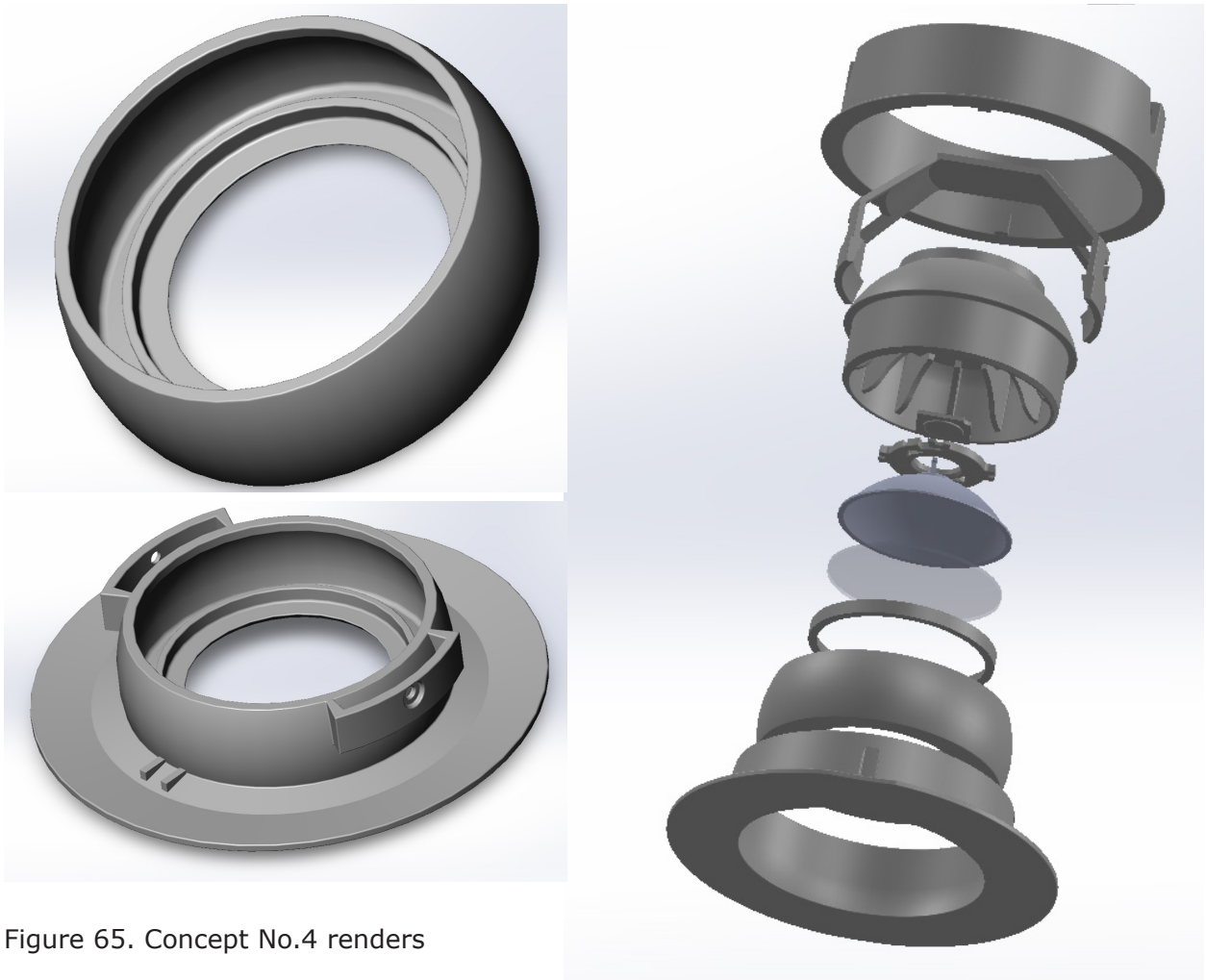


Figure 65. Concept No.4 renders

The feedback from Leksvik Industrimekanikk

In this product, one of the biggest production challenges is finding the right materials and production method for the spring holder. So we went to the Leksvik Industrimekanikk where we met Robert and Helge, the experts and developers in the field of production and metal parts. Their ideas were interesting and efficient so, if I had met them at the beginning of the project I might come up with more different ideas.

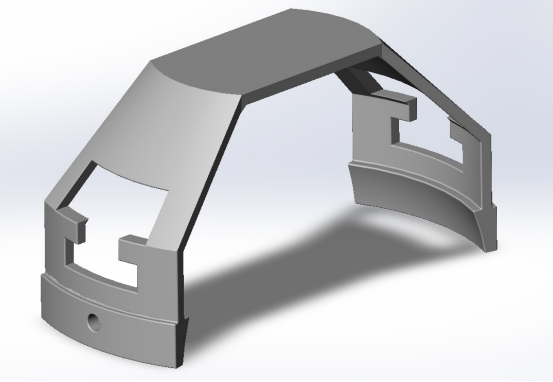


Figure 66. Concept No.4 springs' holder

The result of the meeting was that the designed part with the existing characteristics should be produced by the method of aluminium die casting. However, this is a proposed production method and the result should be tested and evaluated to find a certain option. They suggested redesigning the part and considering it to be produced with sheet metal production, it would be easier to manufacture and more convenient.

In this meeting, we also talked about how to redesign the part that can retain the current features as well. For example, on the surface that is in contact with the housing part 2, controlling the rotational part, could be done by bending the metal. However, their thoughts and ideas were interesting to me, it demands more time and effort than the deadline of the project so I've just sufficed the feedback briefly.

- The aluminium die casting is the right production method but the accuracy on some surfaces is very important that might be difficult to achieve in this production method. We replace the screws with another function. For example, having snaps on the inner surface of the outer ring and the hole on the metal part. You should know the injection moulding companies' ideas about having the snap in the mentioned area.
- The thickness of the part seems good but we have to test it with two different thicknesses and choose the final thickness. When you want to produce the part with sheet metal, you have to skip the circular shape of your design. It should be possible to make it but we might need more time and an innovative idea to decide how to make it. If you think it isn't

necessary to have it we suggest removing it!

- In your design, it is better to think about the steps and works the machines or workers have to do. For example, if you consider the pushing action to assemble it, it is better than fastening the screws.

In this meeting, some of the feedback is only from the production process perspective. So I reminded the technical guys of the main goals of the product, which are circularity and sustainability. For instance, if I consider a snap function that is assembling by pushing and it is not possible to disassemble the part while keeping the pieces intact, it wouldn't be the solution.

In conclusion, it is good to have a technical person's opinion to implement it in the process as the product boundaries enabled you. To be clear, if the only alternative in producing the product is screw function, the slower process in production, we produce fewer numbers of the product daily but instead, they can be disassembled and reused again and we achieved our priority.

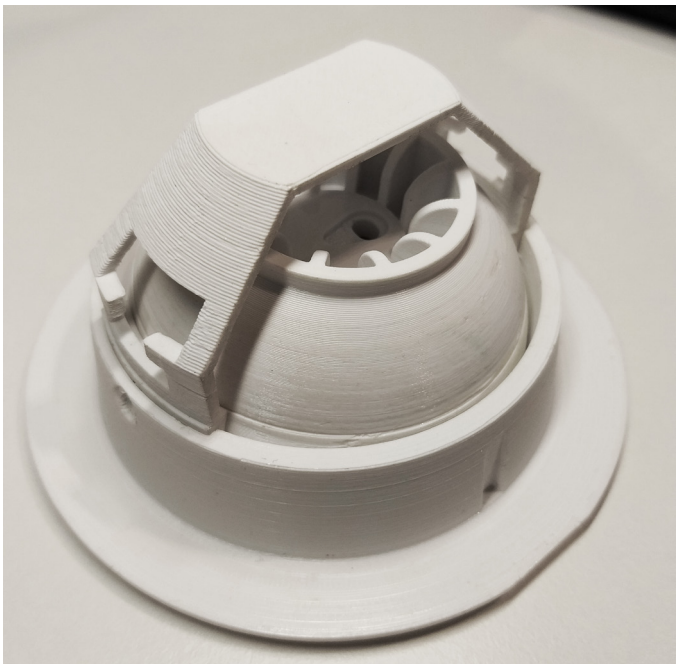


Figure 67. Concept No.4

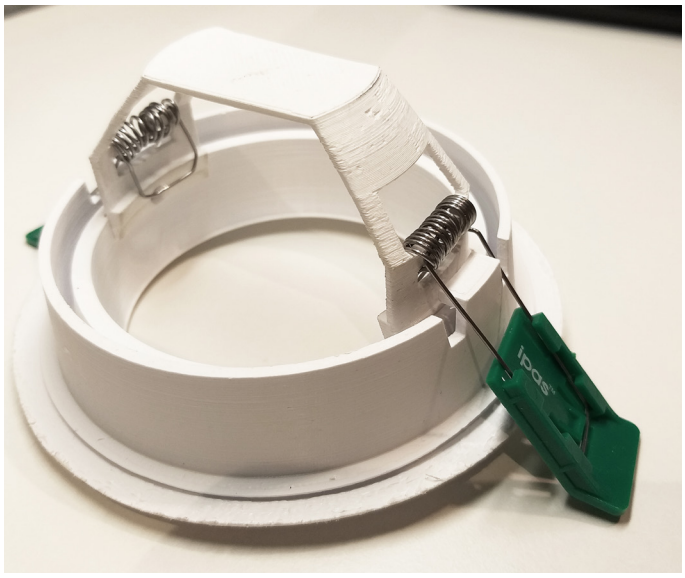


Figure 68. Concept No.4, an experiment with handmade springs

Housing parts 1 and 2: These two parts are easy to assemble and difficult to disassemble. There should be a hole or seam in the edges of these two parts so that they can be separated easier.

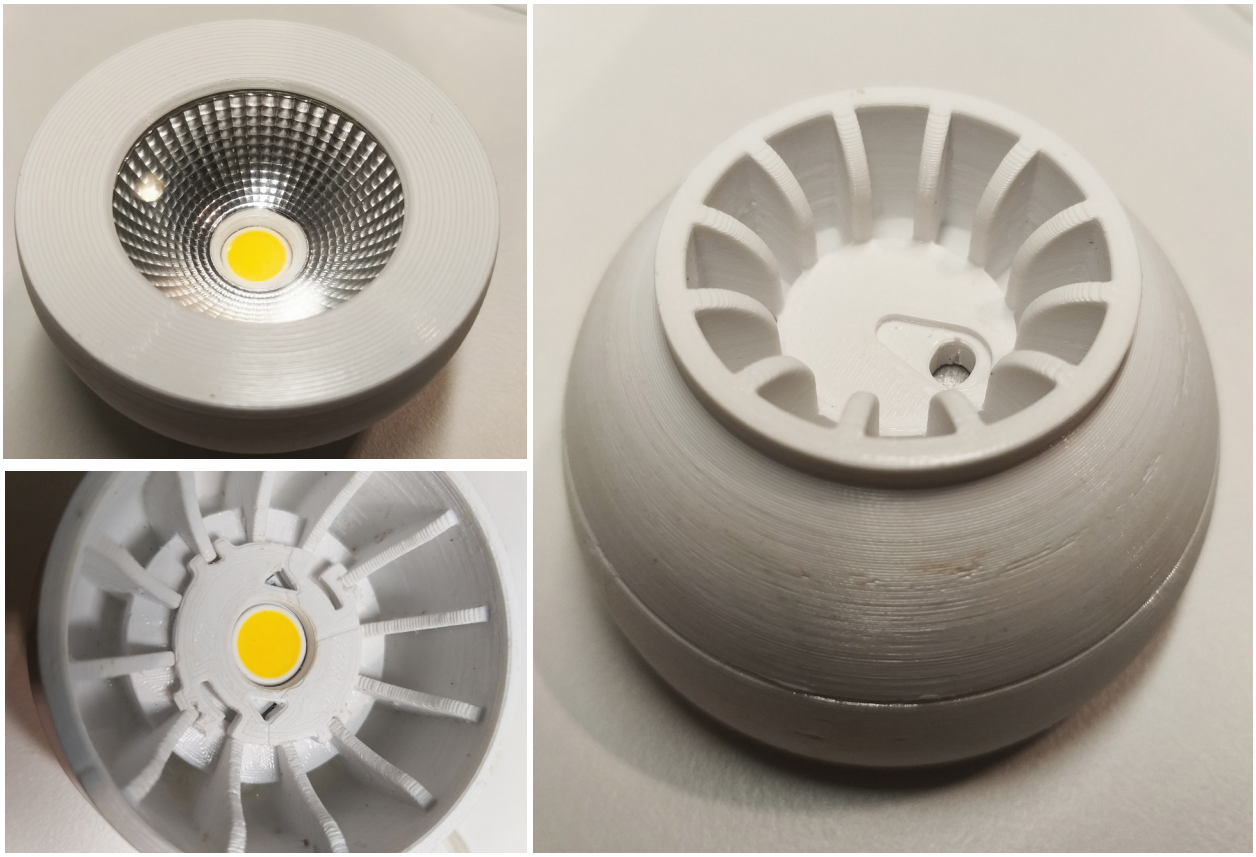


Figure 69. Concept No.4 housing

LED Board/ Holder: I firstly modelled one concept that was in my mind. The mechanism was to be fitted by the fins of the heat sink. The second one was designed since the expected space for the cables was insufficient. After testing the two LED boards, I have figured out some other issues and changed them accordingly. The illustrations show the development of LED holders in the project.

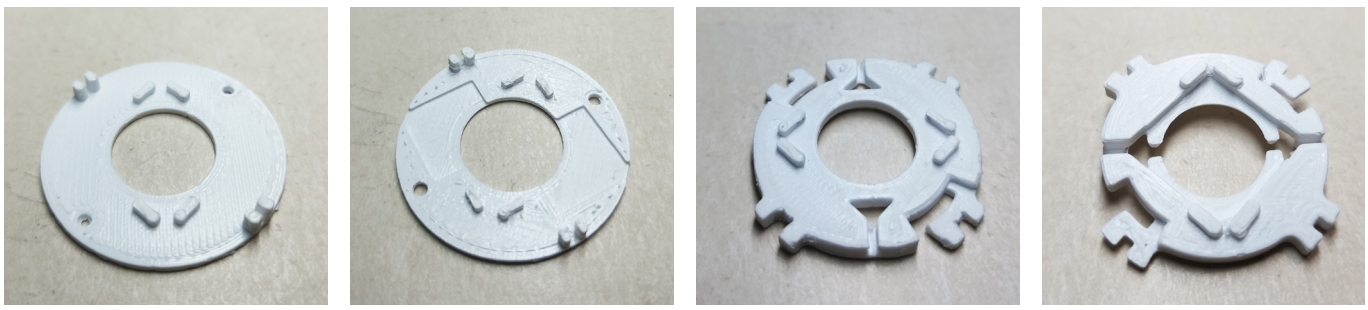


Figure 70. LED holders' development process

The fixed outer ring:

- The undercut problem that IV Group mentioned should be addressed.
- The undercut problem is in both inside and outside of the parts.

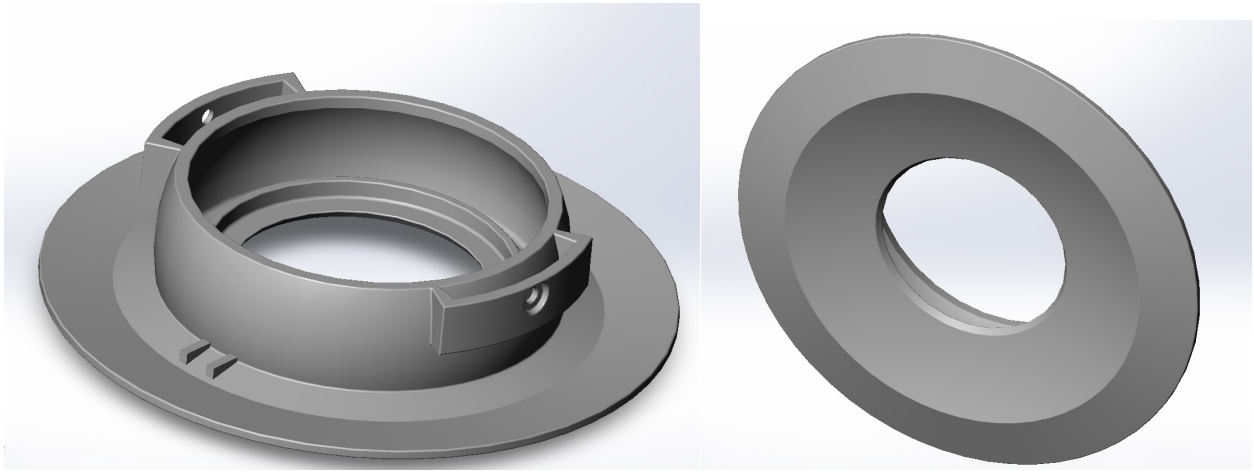


Figure 71. Concept No. 4 fixed ring

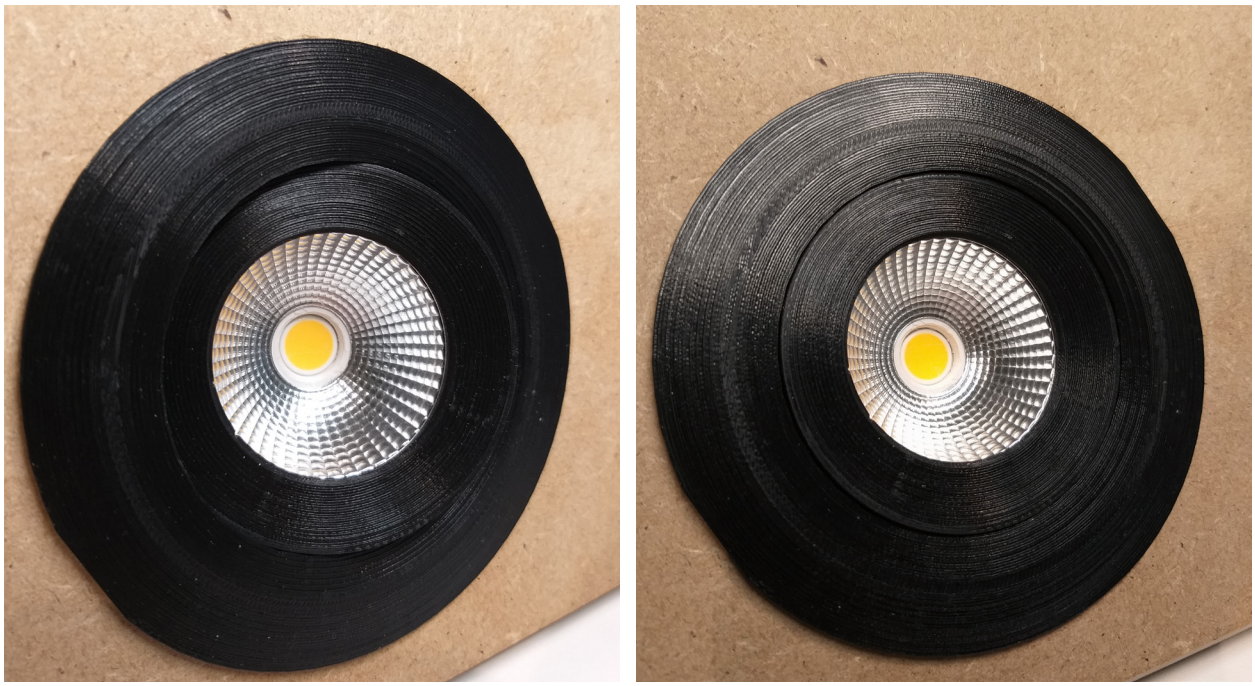
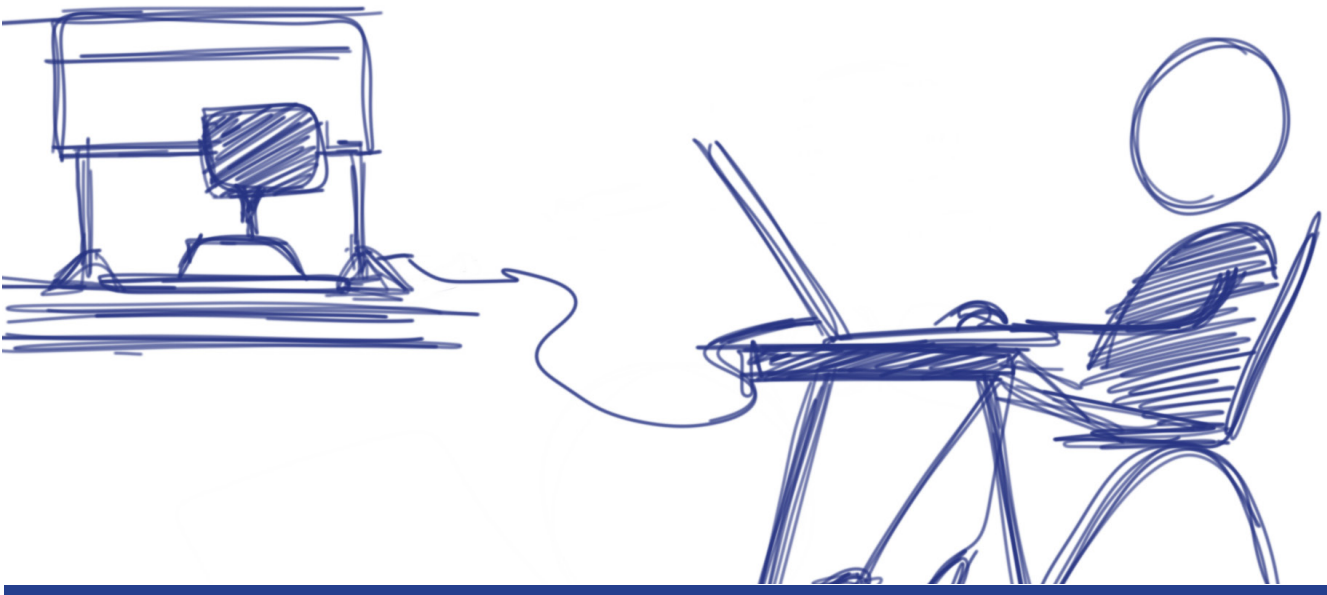


Figure 72. Testing the black color for downlight

Achievements of Develop Phase

1. The production method is an influential part of design yet a clever designer can be active in recommending less typical ways and persuading manufacturers to fulfil project goals.
2. It is good to involve expert people such as experts in material and production in the early stage of the project. They always look at the product from a different point of view.
3. Prototyping is one of the most important parts of product design. By prototyping, one figures out the real problems, faster and more beneficial.
4. Keep the mind open to new thoughts! For example, visiting the 2k machine in the injection moulding company gave me the idea; Instead of painting the outer surfaces of the downlight in order to have a better finishing, it is possible to use a thin layer of virgin plastic for the outer surface and the same type of recycled plastic for the main body. With this idea, we can have one compact plastic part with two different effects on each side, skip adding chemical material to the product and keep the part recyclable.
5. Develop phase leads to a better understanding of the features of each part of the product: The heat sink part should be made out of recycled aluminium. We can have a heat resistant plastic for the heat sink since the temperature of the LED itself is not that much to damage the part but there is no guarantee for the LED lifespan. The reason is that aluminium has a higher thermal conductivity which helps transfer the heat faster from the source. This feature leads to a longer lifespan of the LED and a high-quality product.
6. Testing the current springs on the 3D printed prototype was not very successful but it showed me that these kinds of springs are very strong. The existing downlights are made of metal which is heavy and required stronger springs yet my product is lighter since some parts are considered plastic. So I can define the springs' power, dimension and features in accordance with the new product.
7. In the development phase, I realized that my main focus in the process was on circularity. However I attempt to consider pleasant visual aspects in the design of each individual part, the main innovations and ideations were allocated to the functions and technical features. Therefore for the final product, I should have some ideas for the interface of the downlight.



Deliver

The last phase of the project, Deliver Phase, demonstrates the result and achievements during the months of working on this project. For me, the delivery phase is divided into two parts. One was the company delivery where they wanted to present the concept in the Eliaden exhibition and another for the master thesis.

Final Concept

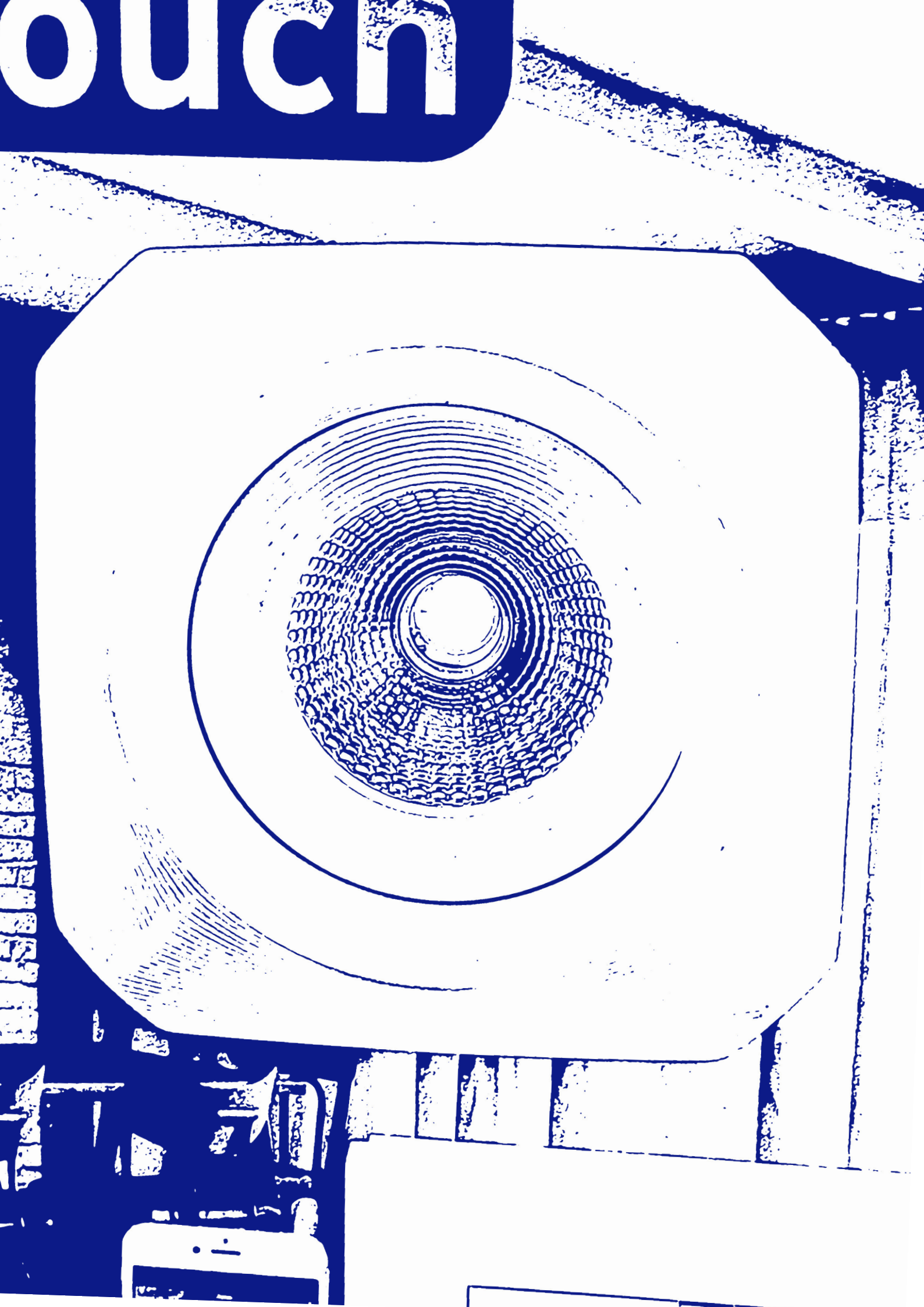
In the final stage, I came up with a series of LED downlights with specific features responding to the circular economy approach. Even though this is only the beginning of the design story, I must make a last mark here as part of the master thesis. But I hope to be able to continue this process to put the last-minute tips into practice.

The delivery part consists of the renders from the 3D model, showing the product with the suggested final materials. The technical drawings for each part indicate the dimensions and details, and the 3D printed prototype clarifies the concept and experiments with some features.

During the concept development stage, I considered a product with a minimum number of parts that some of which are multi-functional. These kinds of ideas are worth thinking about even if they need more investigation in the production process. The springs holder part has this specific feature that I described in detail later in this section.

I've given screwless options in part attachments to make the product easier to dis and assemble. For this purpose different tolerance has been tested in the prototyping phase. I asked the injection moulding company about the specific tolerance in these parts and realized that they usually achieve this effect by experimenting to gain an accurate dimension. There is not a standard for this tolerance since it depends on the material and form of the part. The important factor about this process in the injection moulding is to consider fewer gaps and 3D model the product a bit smaller than the desired size to make it possible to change the cavity with tools.

One of the other considerations in parts of the product is that one part can be used for every other downlight from the same series. For instance, the aluminium housing part can be used for all types of downlights that I have designed. This point is mentioned more in the product description section.

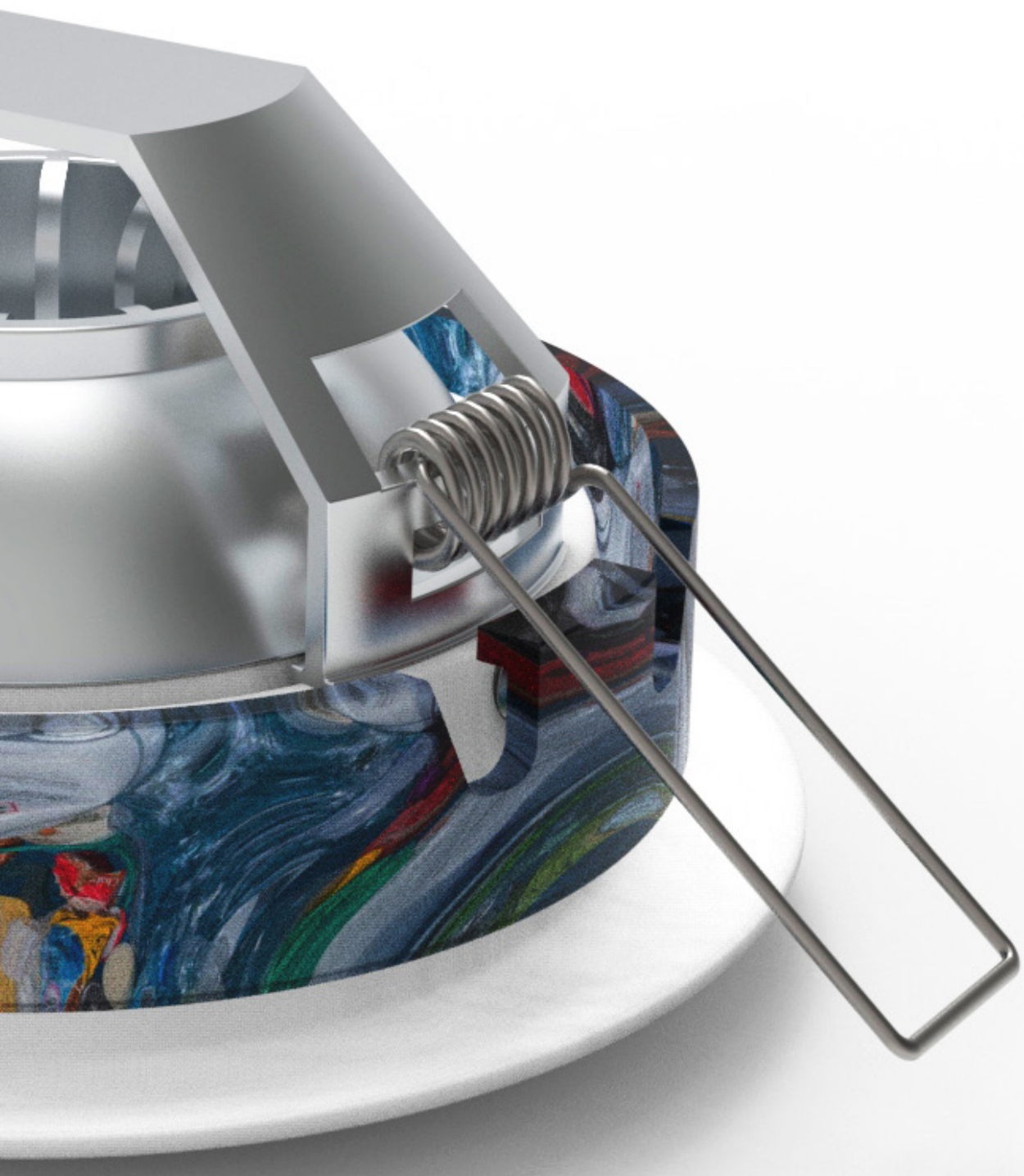

ouch

Circuline® Adjustable Downlight

In this section, the new adjustable downlight has been presented. According to the design brief and as it is mentioned earlier in the thesis, I wanted to keep the features of the previous product of the company and redesign them with a circular approach. So I preferred to have one downlight that is 360° adjustable, one fixed downlight and skip the 2 axises adjustable downlight since we could use the fully adjustable light instead of that. According to circular economy guidelines, design for versatility is one of the factors we could implement in the design process (Kristin Weiser, 2021). With a downlight that is possible to adjust 360°, the electrician could use it everywhere and simply set the beam light angle as they want.

Figure 73. Final adjustable downlight

One of the concerns of the company, in the beginning, was to have the height of the product less than 48mm. I implemented this factor in the design brief and achieved 46mm in the end which is a great scale.360°, the electrician could use it everywhere and simply set the beam light angle as they want.



As the illustration indicates, this product consists of five main parts. The outer frame (main body), housing (heatsink), housing part 2, springs' holder and the protective ring. These names are the specific names that I used to describe the product and not the common names.

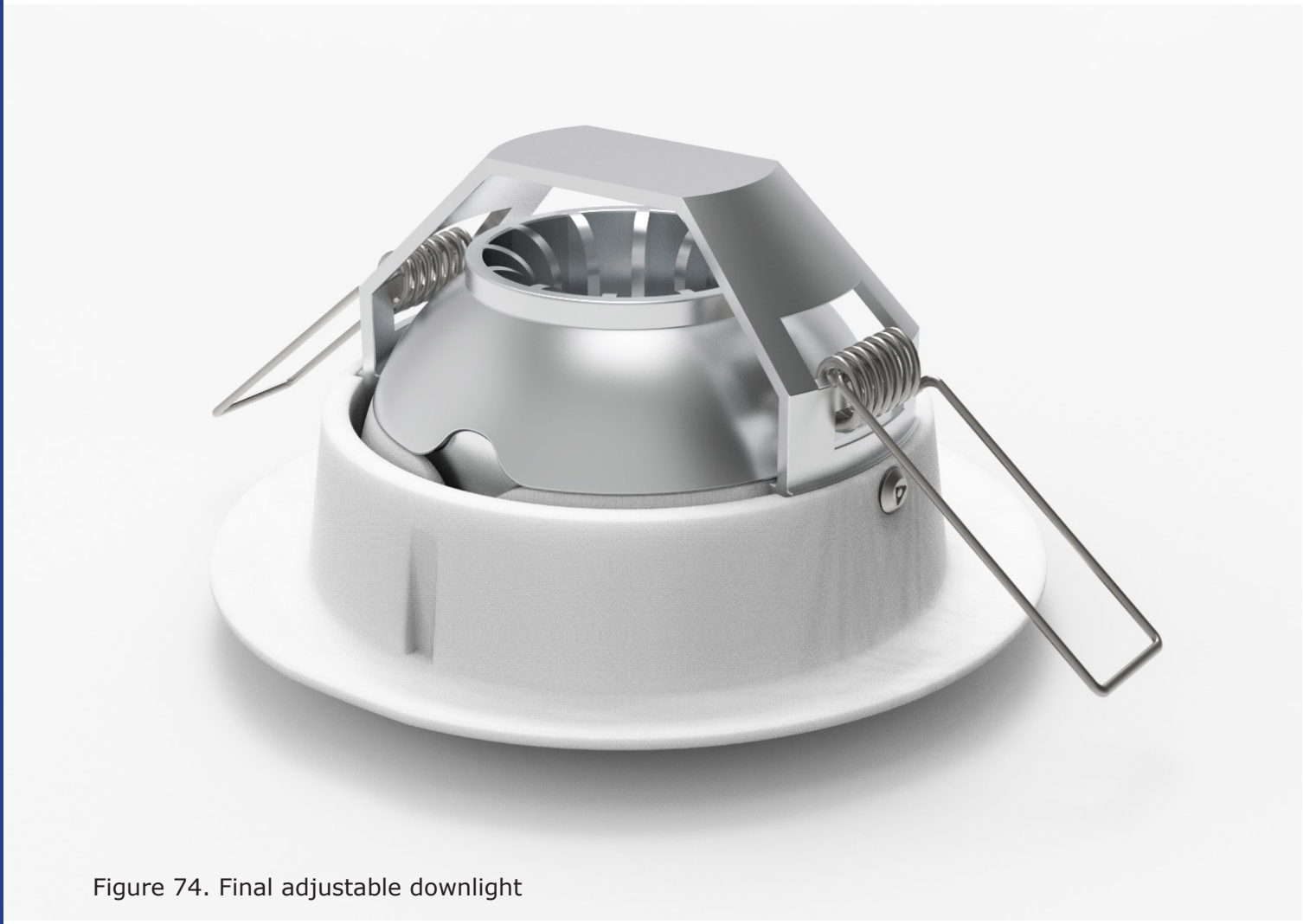
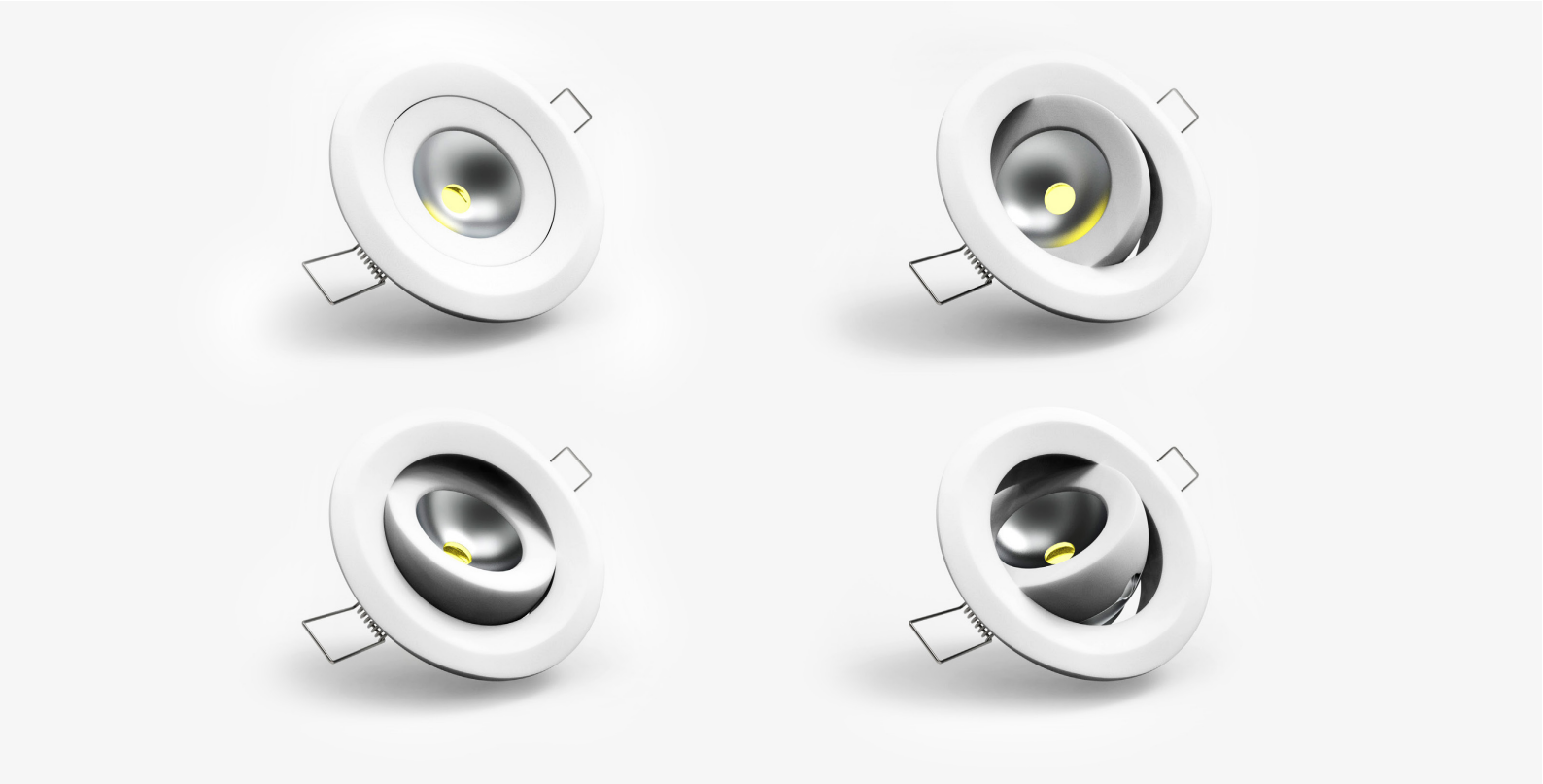


Figure 74. Final adjustable downlight

Figure 75. Final adjustable downlight exploded view

Figure 76. Final adjustable downlight



Outer Ring

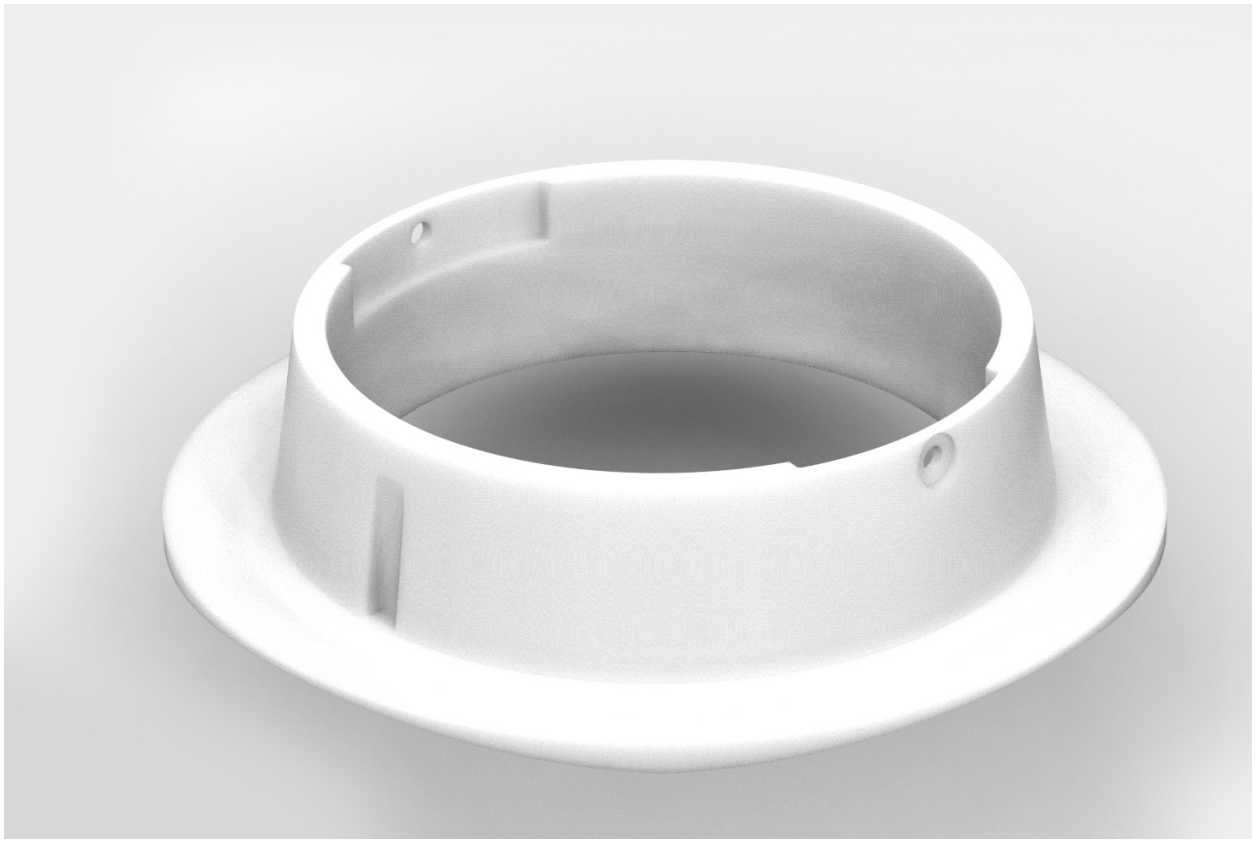


Figure 77. Outer ring

As it has been described in the development part, I considered the outer ring as the main body of the product since the other parts are attached to this part. The outer surface is visible to the user, therefore the finishing is important. This part could be designed in many different forms and colours to be selected by the taste of the end-user.

In the first concept, I've talked about the idea of two specific edges as safe places for placing the hands while taking the downlight out of the ceiling. It continued until the final concept where there are these edges in one of the outer rings. For the other types, I've considered a safe edge by variation of thicknesses that shows the user to place the fingers in the mentioned places.
Insert photos here

Material and production method: the considered material for this part is recycled and virgin plastic both of the same type. The production method is an injection moulding process by the 2k machine. In the 2k machine the nozzle makes the first injection with the recycled plastic, this is the structure of the part that is invisible but the huge amount of material is in this part, the second time the nozzle injects the thin layer of the virgin plastic on the surfaces that are visible and need to be good in finishing.
Due to the last meeting with IV Group, I realized that I have to 3D model the considered details for the 2k machine. It means I have to split the model into two parts, the main part for the first shot and the thin layer for the second shot. But they are not sure about the best thickness of the layers since it is a new material for them and it should be tested to find the best solution.

The type of plastic is not decided yet but PE and Polycarbonate are the suggested materials according to an interview with Vincent, the material specialist. Suggesting the appropriate material for this product needs experiments and expert knowledge that is beyond this master thesis.

Figure 78. Fixed outer ring

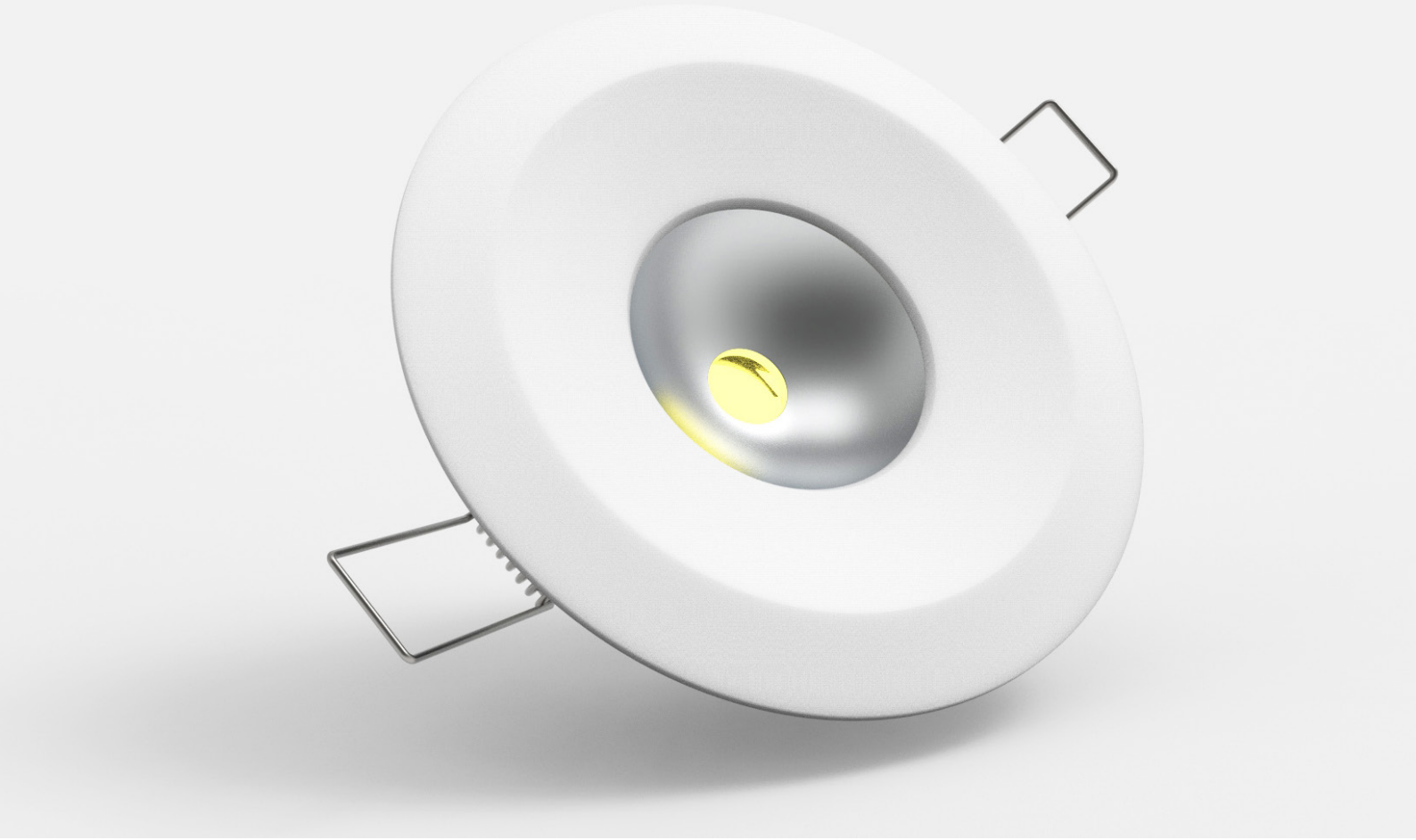


Figure 79. Outer ring No.1

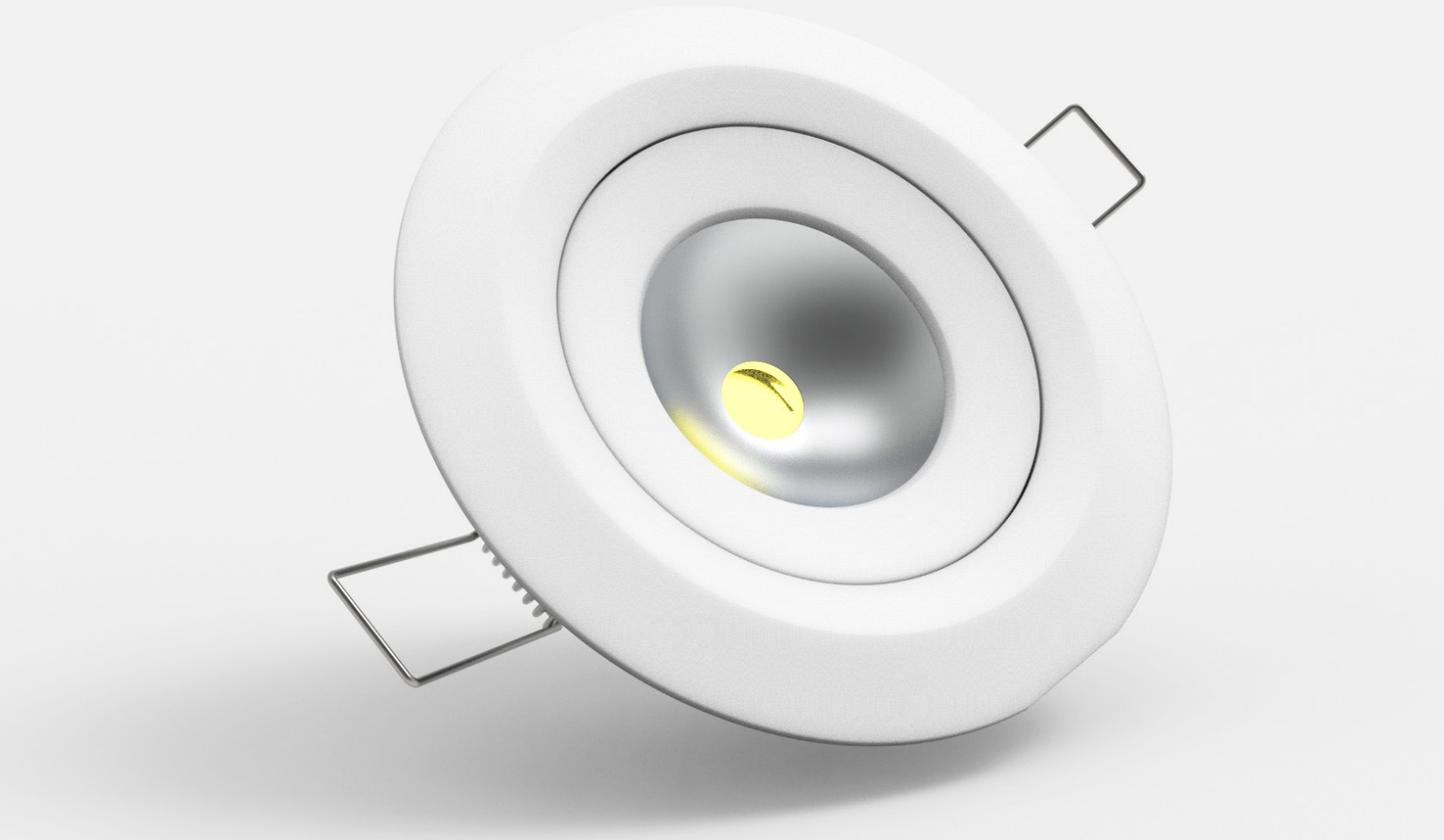


Figure 80. Outer ring No.2

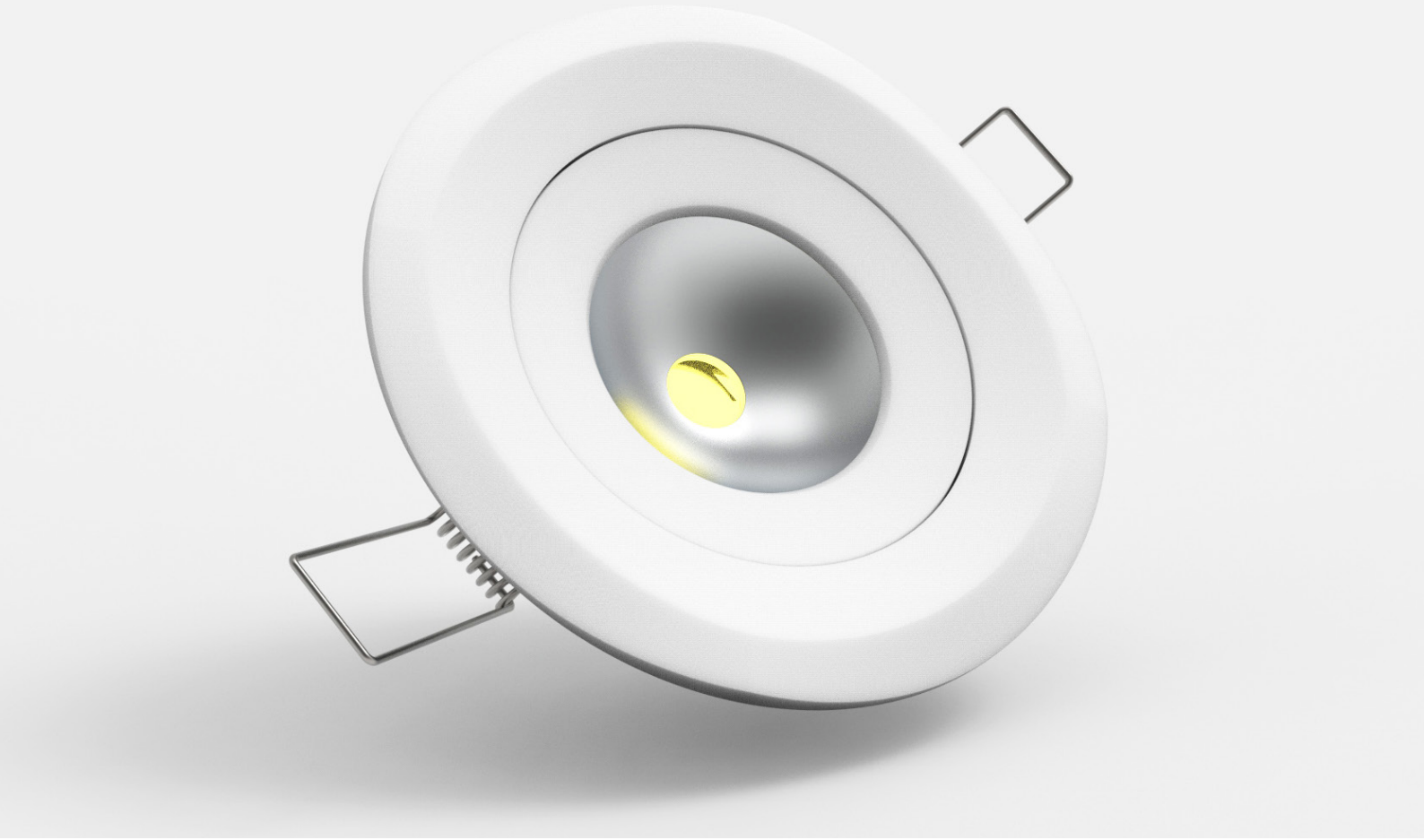


Figure 81. Outer ring No.3

Figure 82. Outer ring No.1

Figure 83. Outer ring No.2

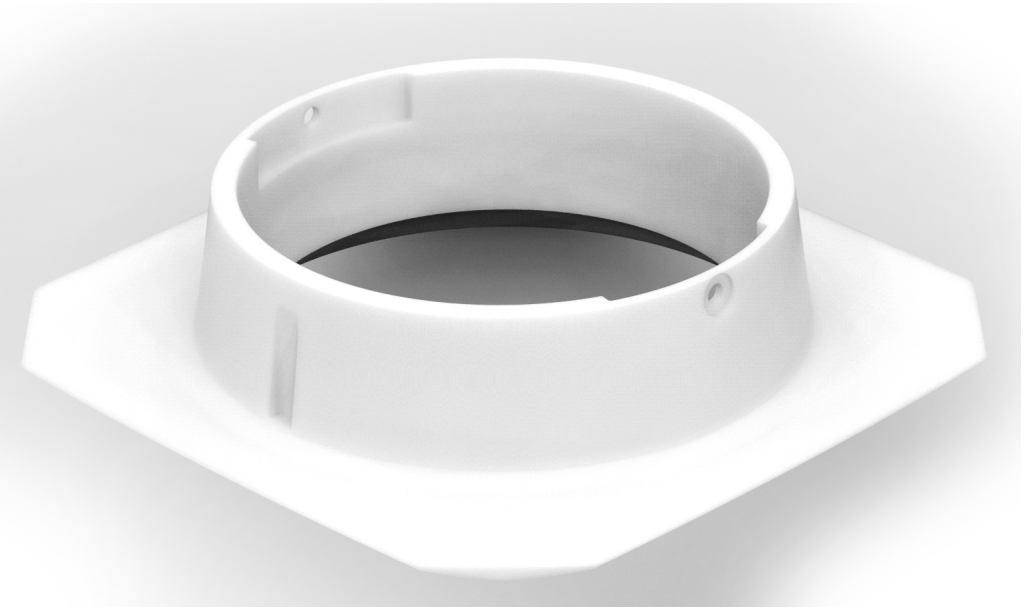


Figure 84. Outer ring No.3

Housing Part 1, Heatsink

Figure 85. Housing P1, heatsink

This part is the most influential part of the downlight to have a longer LED lifespan. After the literature review and observation of the existing products, I decided to have the aluminium heatsink. There is the main cylinder-shaped part in the heatsink, where the LED chip is attached with the thermally conductive adhesives/ thermal epoxy (Lenk, 2011). The primary function of this cylinder is to improve heat transmission from the LED to the fins and from the fins to the outside surface.

Material and production method: The suggested material is recycled aluminium. The analysis shows that the aluminium on the majority of the downlights has been painted. According to interviews and literature review, the only reason for the painting is to have a better appearance for marketing purposes. I suggested this part to be in the original colour of the aluminium without painting since the painting would run our product out of circularity and also is an unnecessary cost and effort. By giving the customer the value of a recyclable and circular product we can ignore the finishing quality that is always hidden in the ceiling and walls.
The production method should be aluminium die casting because it makes the final part resistant to corrosion, creates high conductivity and makes it possible to define the desired accuracy, smoothness and texture.

Figure 86. Housing P1, heatsink

Housing Part 2, Lower Ring

This part that holds the glass, and washer and is in touch with the reflective cup has some visible surfaces on the user side. During the development, I figured out the difficulty to disassemble parts 1 and 2. One solution is to have the screw threads, but it is not a good option since it makes the production process longer and more complicated. Therefore the idea of having a surface depression has been performed, see the renders.

The material and production method: The material is the same as the outer ring, the recycled and virgin plastic with the same production method, 2k injection moulding machine.

Figure 87. Housing P2

Springs’ Holder

Figure 88. Springs’ holder

The reason why I designed this part was to hold the springs and also to control the rotation part. From the early stage of ideation, I concluded that the existing springs are strong and need a metal base for attaching. If I wanted to connect them directly to the plastic part, I am taking part in the breakage risk, it is the opposite of to project goals. Therefore I've designed a kind of springs holder with two purposes. Keeping the springs in the right place and controlling the rotational part. The spring holder should be attached to the main body with two special types of screws.

In the discovery part, I've raised the issue of repairing the product by professional people inside the company, so I've presented the idea of having specific kinds of screws that only professionalists have the tools for opening. So despite the longer disassembly process, there is the opportunity of doing this work only inside the company. It is also worth noting that having two screws in comparison to the number of screws that are in existing products, is a beneficial improvement.

The material and production method: This part also should be made from recycled aluminium and produced by aluminium die casting.

Figure 89. Screw

The screws: The screws type should be something new. In this design I didn't go through the market alternative, the purpose so is to have them unique.

Protective Ring

Figure 90. Protective ring

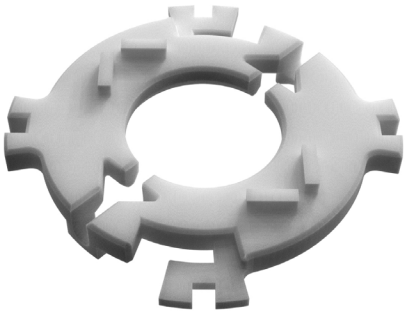
As its name shows, this ring protects the electricians' fingers from being hit by the springs. This part also has another purpose, to make the product suitable for inserting into larger cut-outs.

Interviews informed me about the different cut out dimensions. Today the most common size is 76mm, but some places still have the cut-out of 83mm. For this reason, I designed this ring to make the downlight fit better in the larger holes.

Material and production method: The material is recycled plastic. For its visual aspects and exaggerating the importance of recycled material in the downlight, I imagined a random mixture of colours that comes from melting different plastics. Even if on the industrial scale of producing this part it is impossible to have the same visual effect as in renders, I think that's a smart marketing strategy which highlights the product values and shows the market that there is no need to have a pure colour and shiny finishing in the product.

Specific feature: The part exists of two cutting forms in the surface edge to allow the springs to land on the false ceiling. When the electrician wants to take the downlight out from the ceiling they can hold this ring with one hand and pull the downlight with the other hand, the springs will get stuck inside the hole, when the trapped springs and downlight are completely out of the ceiling, the electrician could turn the springs to the normal position slightly and without damaging to ceiling or hands. The opposite process is for installing the downlight, and this ring helps the springs to be released slowly and carefully and avoid breaking the thin false ceilings.

LED Holder



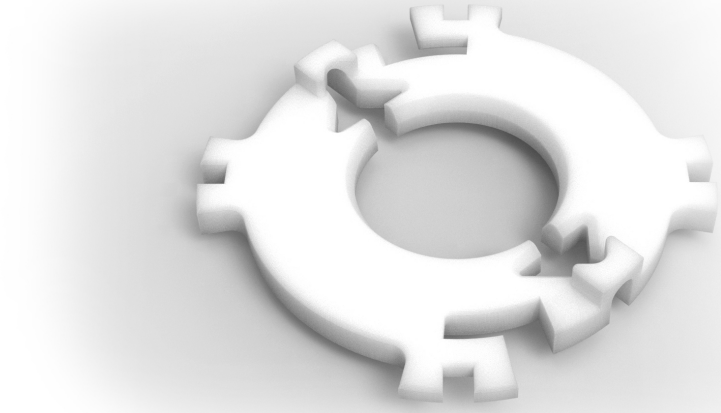


Figure 91. LED holder

This small plastic board is responsible for holding the LED chip and reflective cup. In the concept development, I've described this part in detail. In the final product, several related issues have been solved in accordance with the requirements and dimensions of other parts. For its specific design, I've removed the old mounting style, which is screws. The renders illustrate the attaching mechanism of the reflective cup to this board.

Reflective Cup

Figure 92. Reflective cup

This part is attached to the LED holder and reflects the light.

Material and production method: The existing samples are made of aluminium-coated plastics. My suggestion is to produce them with recycled aluminium. The point is that, making this part with plastic and coating it with aluminium, makes the part almost non-recyclable. There is no need to have a huge amount of aluminium for this part, it could be a very thin layer. One possibility for producing this part is aluminium injection moulding with a shiny surface.

CircuLine® Fixed Downlight

The only distinction is the fixed outer ring in this product. We can skip part 2 of the housing (the lower ring) and attach the housing part 1 (heat sink) directly to the outer ring. The other parts can be used for this product since the dimensions are the same.

The material and production method: this part is similar to the outer ring. So the material and the production method are the same. After the feedback from IV Group, I've implemented injection moulding guidelines for the part. For example, for the undercutting problem under the screw part, I make two small surfaces straight to make it possible to produce. See the renders.

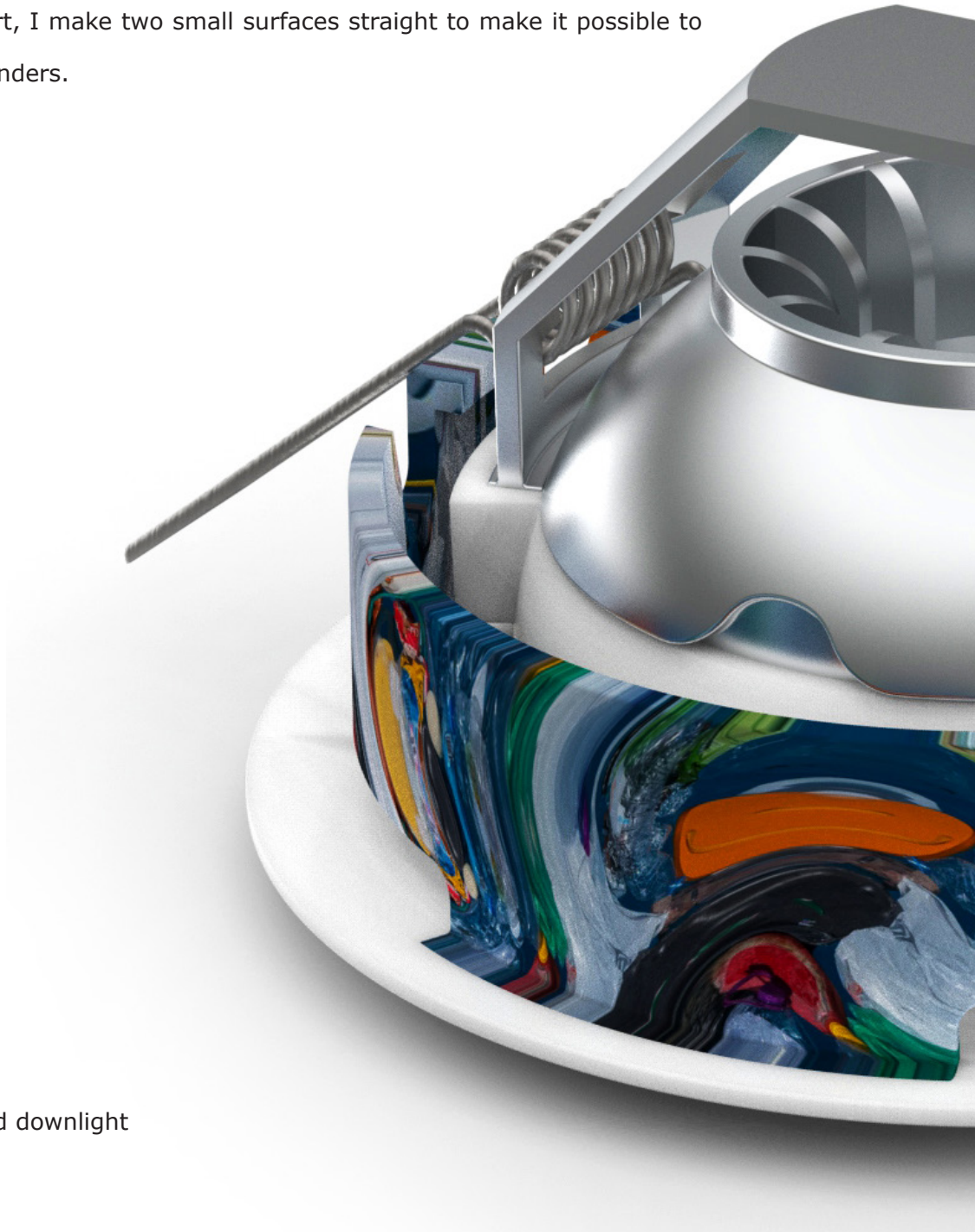
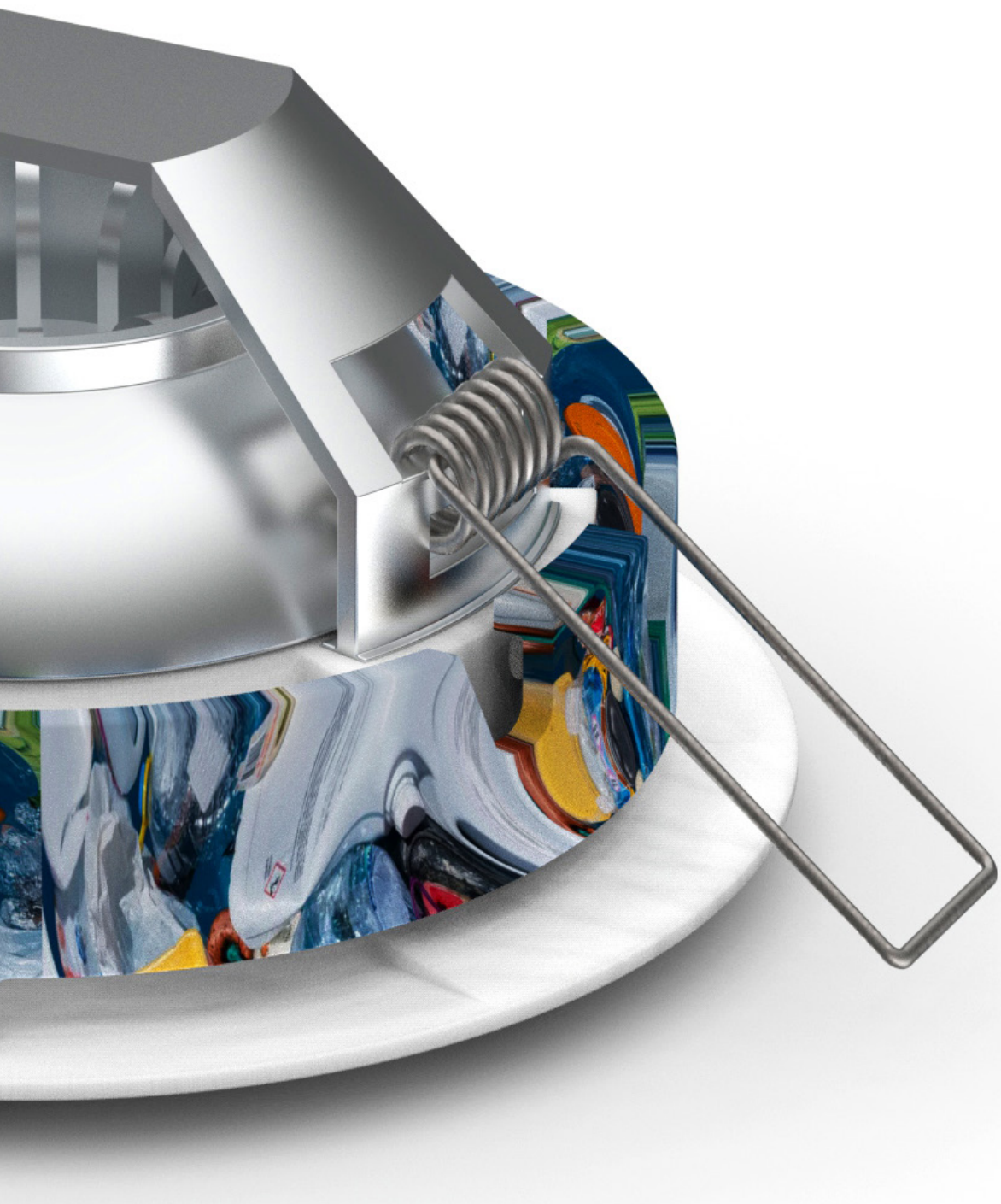


Figure 93. Final fixed downlight



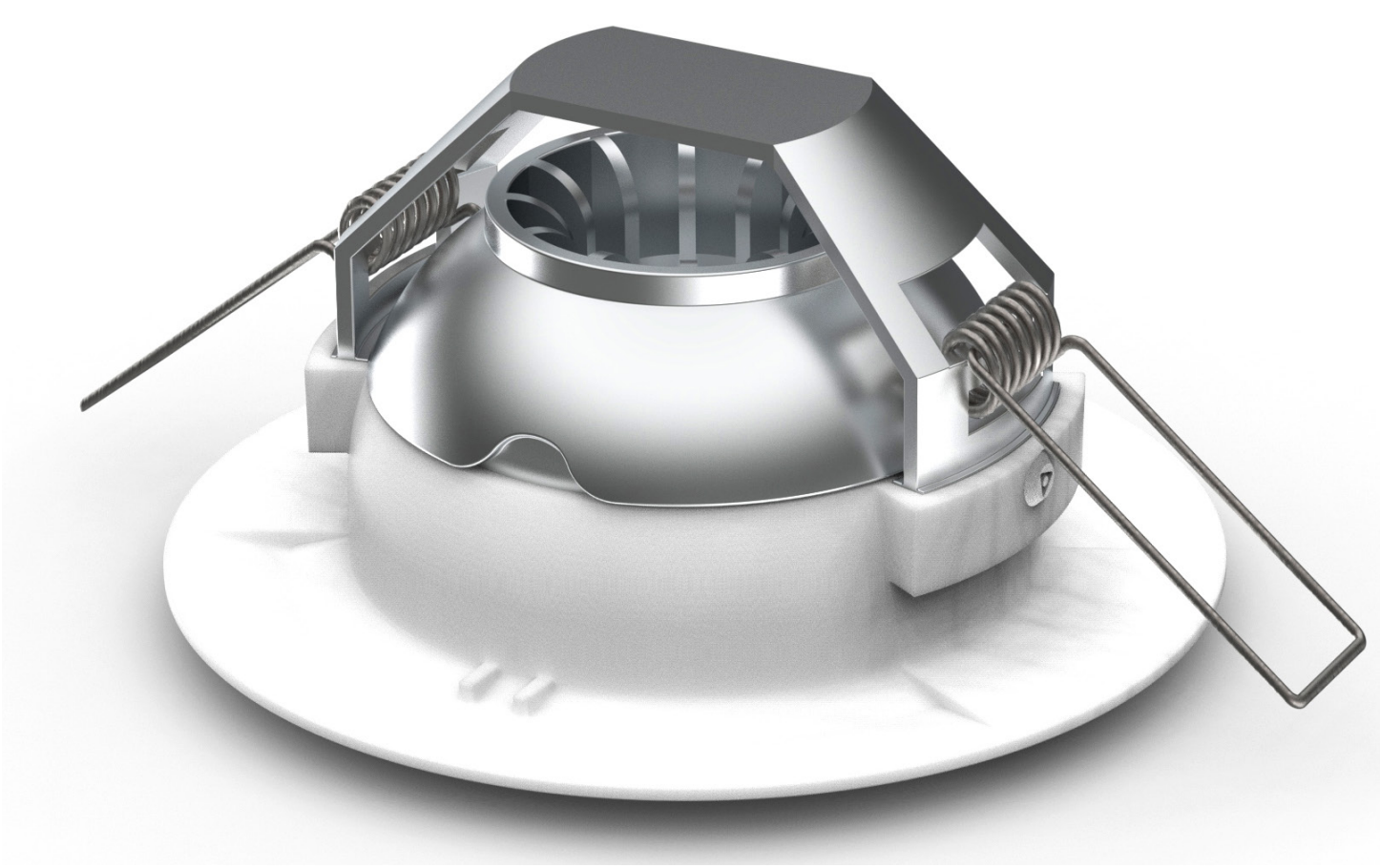


Figure 94. Final fixed downlight

Figure 95. Fixed outer ring

Prototype

Figure 96. Prototype samples

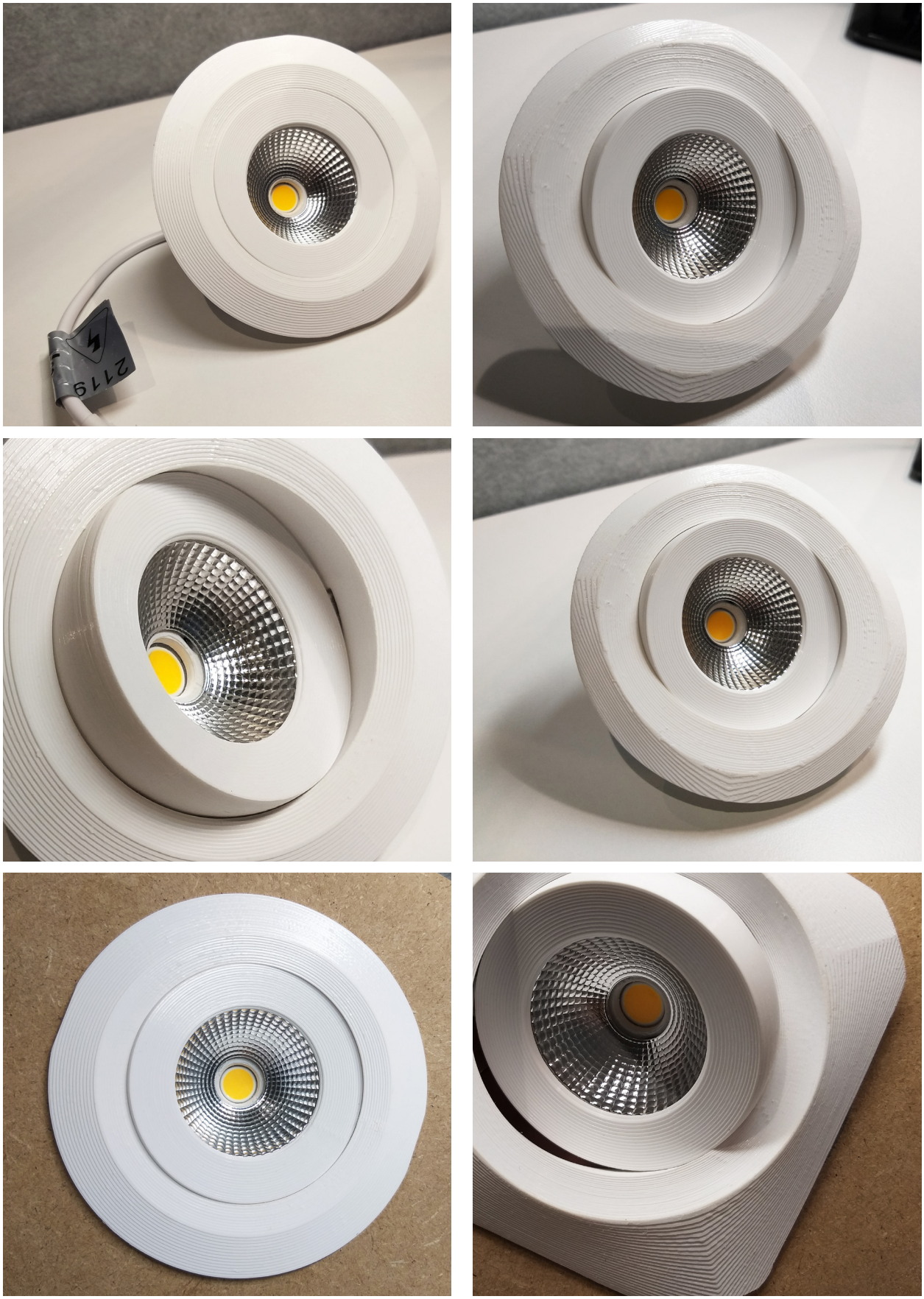


Figure 97. Prototype samples

Eliaden Exhibition

Eliaden, one of Norway's greatest trade fairs, was held at NOVA Spektrum in Lillestrm from May 31 to June 2, 2022. Over 19,000 visitors saw items from exhibitors in the energy, industrial, automation, and electrical installation fields at this expo. CTM Lyng, along with every other supplier, attended the exhibition and exhibited the company's latest products and ambitions.

It was a huge honour for me that CTM Lyng chose to present my CircuLine® downlight design for the first time at this exhibition. According to Terje Lillemo, CEO of CTM Lyng, the concept was showcased to over 250 clients at the exhibition and received overwhelmingly positive feedback.

Figure 98. Posters for Eliaden exhibition

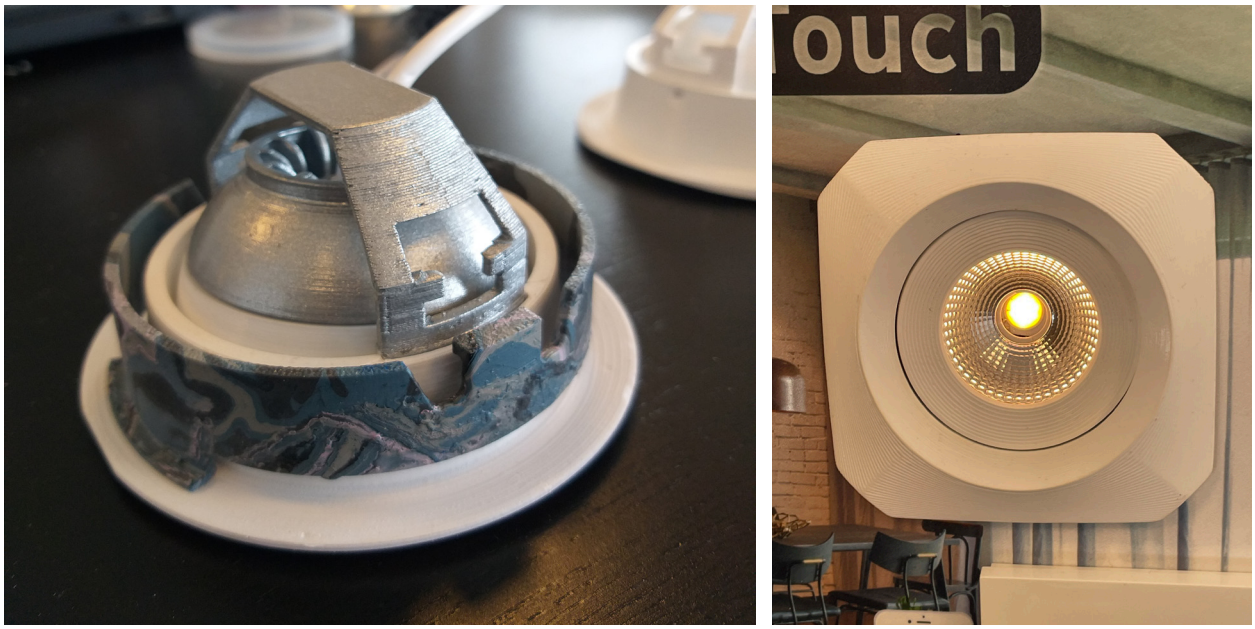


Figure 99. Prototypes for Eliaden exhibition

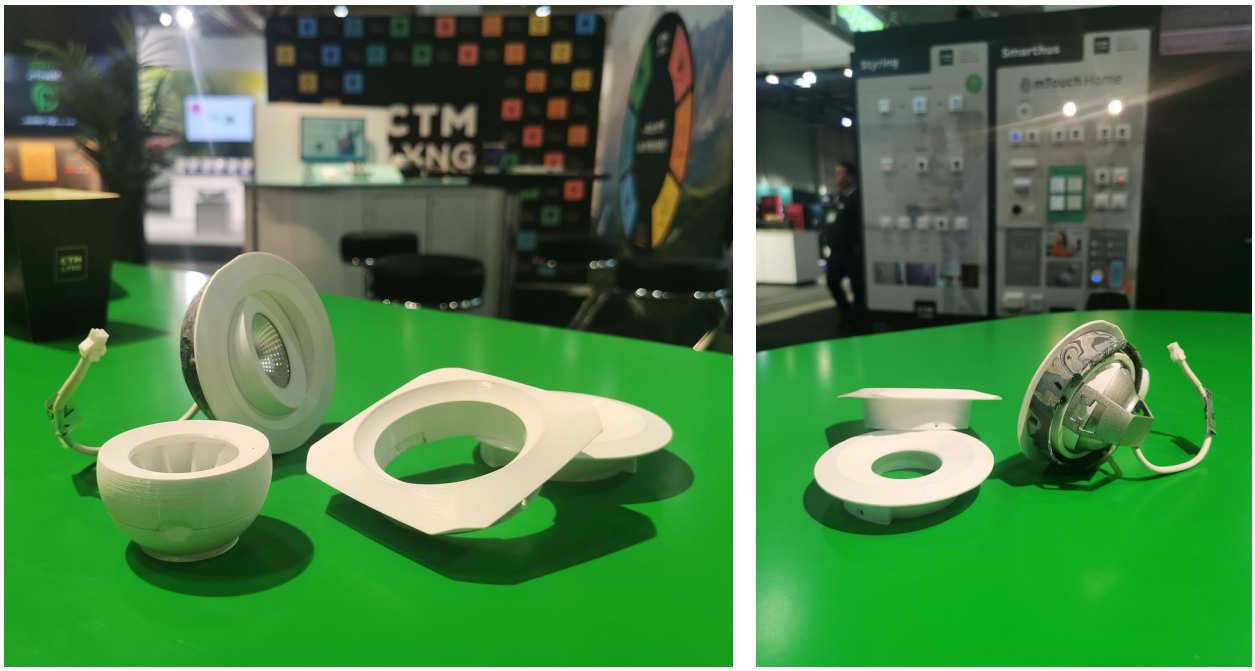


Figure 90. CircuLine® downlights, Eliaden exhibition,

Photo: Brage Stenberg Johnsen.

Evaluation (Pros & Cons)

I've requested CTM Lyng to provide comments on my project so that I may discover the advantages and disadvantages of the products I've designed. Their ideas were quite impressive and impactful.

In general, they were impressed by my creativity and approach to the challenges. "You looked at the product from a different viewpoint, and we are excited by this approach," I heard multiple times during the discussion and again in the feedback review. This motivated me to pursue innovative solutions rather than limiting the design requirements to material and production process concerns. (See the attachment)

According to the comments, there are some additional aspects, that need to be addressed in the future; including the positioning of the electric wire, the attachment of the LED, and the light diffusion. I am also aware that some aspects of the product would benefit from rethinking some details.

I showed the prototypes to the Nortek Elektro electricians in order to study more about the pros and cons. The outcome surprised me; the electricians just care about the installation. Their favourite feature was the mechanism that prevented the springs from touching their fingers. They also asked about the final surface polish and the height of the product, which they measured with their metre, but they did not give much emphasis to the other aspects of the product. I conclude that the problems I addressed in the product are more relevant for the producer and those who care about the environment.

One of the electricians' useful remarks was concerning the protective ring. He said, "Do you consider this part is truly required for the product?" He then continued, "I assume this section is no longer necessary if we know where to put our fingertips."
Given that I also presented the idea of slowly releasing the springs on top of the ceiling, this might be a vital component of the product; nevertheless, further experiments and assessments are required to address this question.

Figure 91. Terje Lillemo (CEO) and two other CTM Lyng employees are showing the product in the Eliaden exhibition. Photo: Brage Stenberg Johnsen

Future of Product

This project provided me with an excellent experience in the world of product design. I learned a lot and had a great time working on this project. However, certain assumptions must be reviewed before launching the final product on the market. The whole concept satisfied me and pushed me to continue working on this project.

During the project, I thought about an alternative for the springs. It was challenging and required more tasks, though I believe this was a good starting point which could be continued in the future. There was not enough time to achieve this goal since each idea required separate prototyping and experimenting. Yet, this is an area with many opportunities that fewer producers have noticed.

In terms of long-lasting solutions, there is the issue of components' lifespan. By a brief literature review, it is conducted that an effective heatsink increases the lifespan of the components to a large extent. It was also interesting to see how the engineering software helps to achieve the best solution for the heatsink by thermal simulation. In general, it is not a designer's job to simulate the thermal issues, but the cooperation between a designer and the engineer could improve the product quality.

Various meetings with the manufacturers impressed my design criteria. Earlier in my bachelor's, I was awarded for the importance of the manufacturing process in designing, this project, however, was a great chance to implement the innovative ideas and align them with the manufacturing process. In words of future developments, I expect some parts to be redesigned that are either difficult to produce or hard to identify the appropriate manufacturer in Norway, particularly in the Trøndelag region.

References

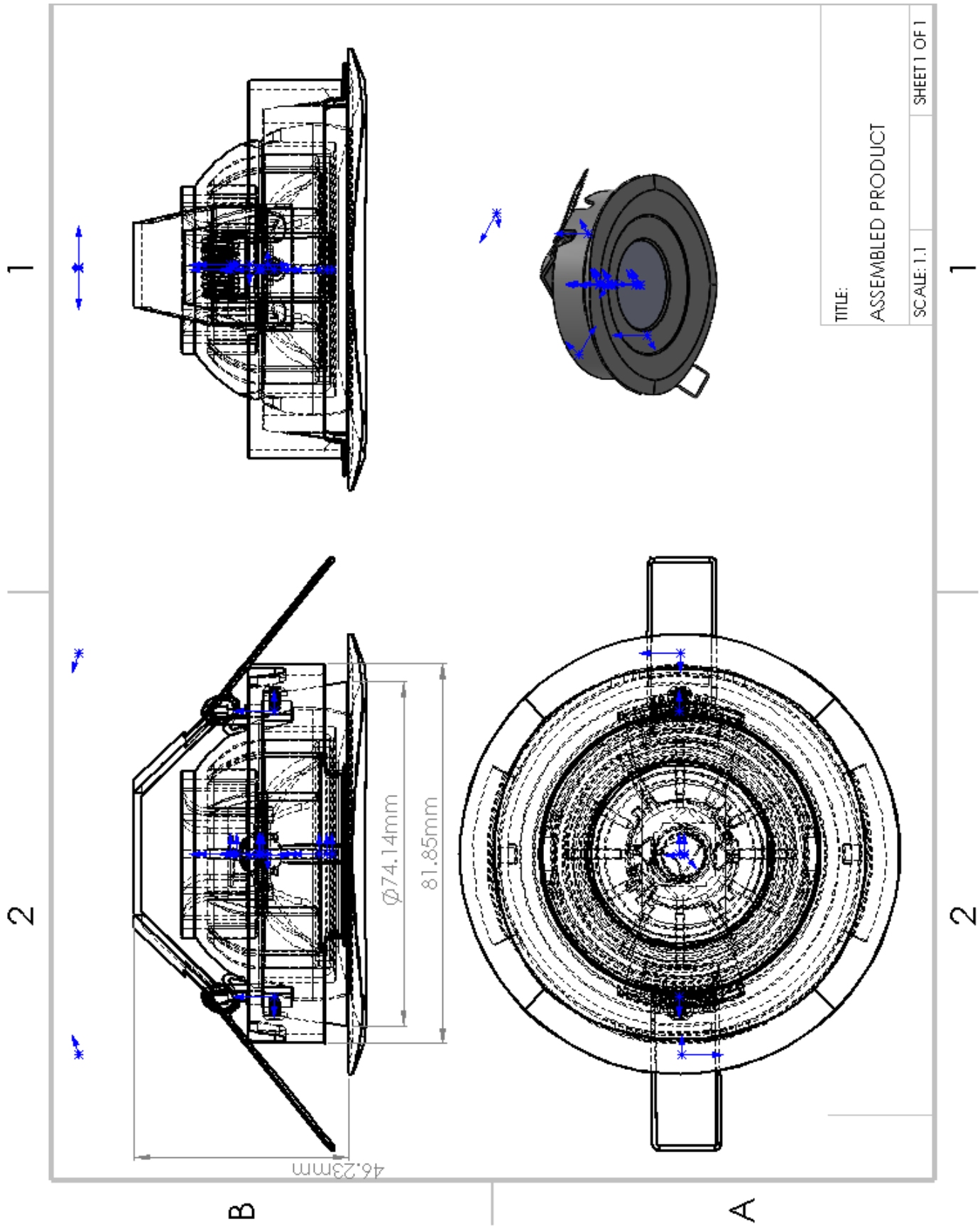
- Crocker, R. Chapman, J. The Routledge Handbook of Sustainable Product Design-Routledge. P250. 2017
- https://www.un.org/sustainabledevelopment/sustainable-consumption-production/
- https://ctmlyng.no/wp-content/uploads/Press-release-Circuline.pdf
- Lobos, A. Chapman, J. The Routledge Handbook of Sustainable Product Design-Routledge. P151. 2017.
- Preston, F. A global redesign? Shaping the circular economy, 2012. https://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/bp0312_preston.pdf
- Kristin Wieser, M. Circular Design Guide for the Use of Plastic in Furniture. Master Thesis, NTNU. P22, 328, 329. July 2021.
- Sillanpää, M & Ncibi, C. The Circular Economy: Case Studies about the Transition from the Linear Economy. P7 . 2017. https://books.google.no/books?id=TxGnDwAAQBAJ&printsec=frontcover&dq=inauthor:%22Chaker+Ncibi%22&hl=en&sa=X&redir_esc=y#v=onepage&q&f=false
- Grigoropoulos, Doulos, L. T., Zerefos, S. C., & Tsangrassoulis, A. An overview of environmental impacts of lighting products at the end of life stage through life cycle impact assessment. IOP Conference Series. Earth and Environmental Science, 899(1), 12040. 2021. https://doi.org/10.1088/1755-1315/899/1/012040
- Mugge, R. Chapman, J. The Routledge Handbook of Sustainable Product Design-Routledge. P386, 387, 375. 2017.
- Ellen Macarthur Foundation, Towards the Circularity Economy, Economic and business rationale for an accelerated transition, P24. 2015.
- https://www.werktrends.nl/app/uploads/2015/06/Rapport_McKinsey-Towards_A_Circular_Economy.pdf
- https://www.sg-as.com/products/downlightbox
- Elesi, 2019. 'What Are IP Rated Downlights?'. https://www.elesi.com/blog/what-are-ip-rated-downlights/#:~:text=IP%20(in%20IP%20Rating)%20stands,water%20or%20solid%20object%20intrusion.
- Mccarey, A, 2020. 'IP Rating of Light Fixtures Explained'. https://www.mullanlighting.com/blog/ip-rating-of-light-fixtures-explained/?___store=en&___from_store=en

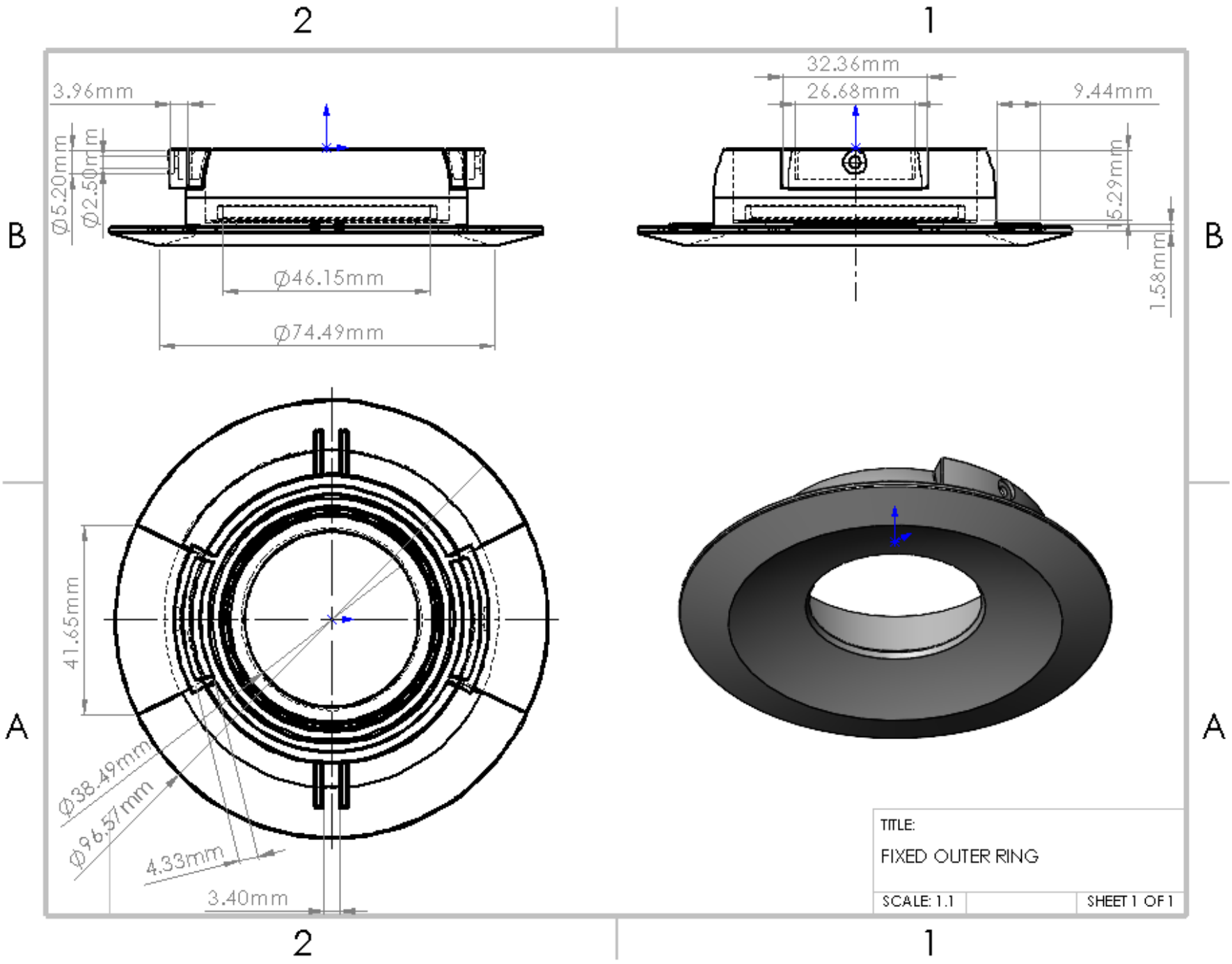
- https://www.amazon.co.uk/Downlights-Dimmable-Recessed-Ceiling-Adjustable/dp/B07Z4NZKTF/ref=rtpb_sp_bmx_dp_9f3e35bo_3/257-2799877-7724030?pd_rd_w=nubYp&pf_rd_p=8ec9bef7-8669-4919-8343-2b6fe884805e&pf_rd_r=KZWC05YFD7ATWPEG3239&pd_rd_r=20d314f3-c455-48ff-92ff-dbbbb04b6ce5&pd_rd_wg=Ysd3x&pd_rd_i=B07Z4NZKTF&th=1
- https://www.amazon.co.uk/Brite-Source-Solo-Rated-Downlight/product-reviews/B01LB97UD8/ref=cm_cr_arp_d_viewopt_srt?ie=UTF8&reviewerType=all_reviews&filterByStar=critical&pageNumber=1&mediaType=all_contents&sortBy=recent
- Park S, Jang D, Yook S & Lee K, 2016. 'Optimizing a chimney design for cooling efficiency of radial heat sink in a LED downlight'.
- Hussaini A, 2015. 'LED Heat Sink Thermal Simulation'. https://www.simscale.com/projects/ahmedhussain18/thermal_analysis_of_heat_sink_led/
- Siniscalco A, 2021. 'New Frontiers for Design of Interior Lighting Products'. p78
- Trondheim Renholdsverk, 2022. 'Slik gir Vincent (39) plastavfallet nytt liv'. https://trv.no/rastoff/slik-gir-vincent-39-plastavfallet-nytt-liv/
- Van Weelden, E., Mugge, R. and Bakker, C. (2016) 'Paving the way towards circular consumption: Exploring consumer acceptance of refurbished mobile phones in the Dutch market', Journal of Cleaner Production, vol 113, pp743–754
- org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/bp0312_preston.pdf (accessed 3 May 2015)
- Arnold G. Efficiency Vermont SSL Programs 2009. In: ENERGY STAR Lighting Partners Meeting, San Antonio, TX; 2009.
- Bong-Min Song, Bongtae Han, Avram Bar-Cohen, Mehmet Arik, Rajdeep Sharma, Stan Weaver, Life prediction of LED-based recess downlight cooled by synthetic jet, Microelectronics Reliability, Volume 52, Issue 5, 2012, Pages 937-948, ISSN 0026-2714,https://doi.org/10.1016/j.microrel.2011.04.014.
- Scully T. 2019. "Why You Need an LED Heat Sink: Increasing light output & extending your LEDs lifetime".https://www.ledsupply.com/blog/why-you-need-an-led-heat-sink/
- Lenk, R & Lenk, C. "Practical Lighting Design With LEDs", First Edition. 2011. the Institute of Electrical and Electronics Engineers, Inc. Published 2011 by John Wiley & Sons, Inc, Chapter 6

- https://eliaden.no/om-oss/
- https://www.amazon.com/Lithonia-Lighting-6SL-07LM-90CRI/dp/B075F4KBJ5/ref=sr_1_58_sspa?crid=3MLHYDVIOY4VM&keywords=downlight%2Bwith%2Bintegrated%2Bdriver&qid=1645618600&sprefix=downlight%2Bwith%2Bintegrated%2Bdrive%2Caps%2C141&sr=8-58-spons&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzOE40NklLRFo0SFpJJmVuY3J5cHRlZElkPUEwMDE1OTI1M09WNDNEQjZFUElIMCZlbmNyeXB0ZWRBZElkPUEwMTI5ODU3MjBWTzJGNDVXTlFLNyZ3aWRnZXROYW1lPXNwX2J0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU&th=1

Appendix

- Dimensions: This section presents the general dimensions for the final product.

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15.29mm
1.58mm
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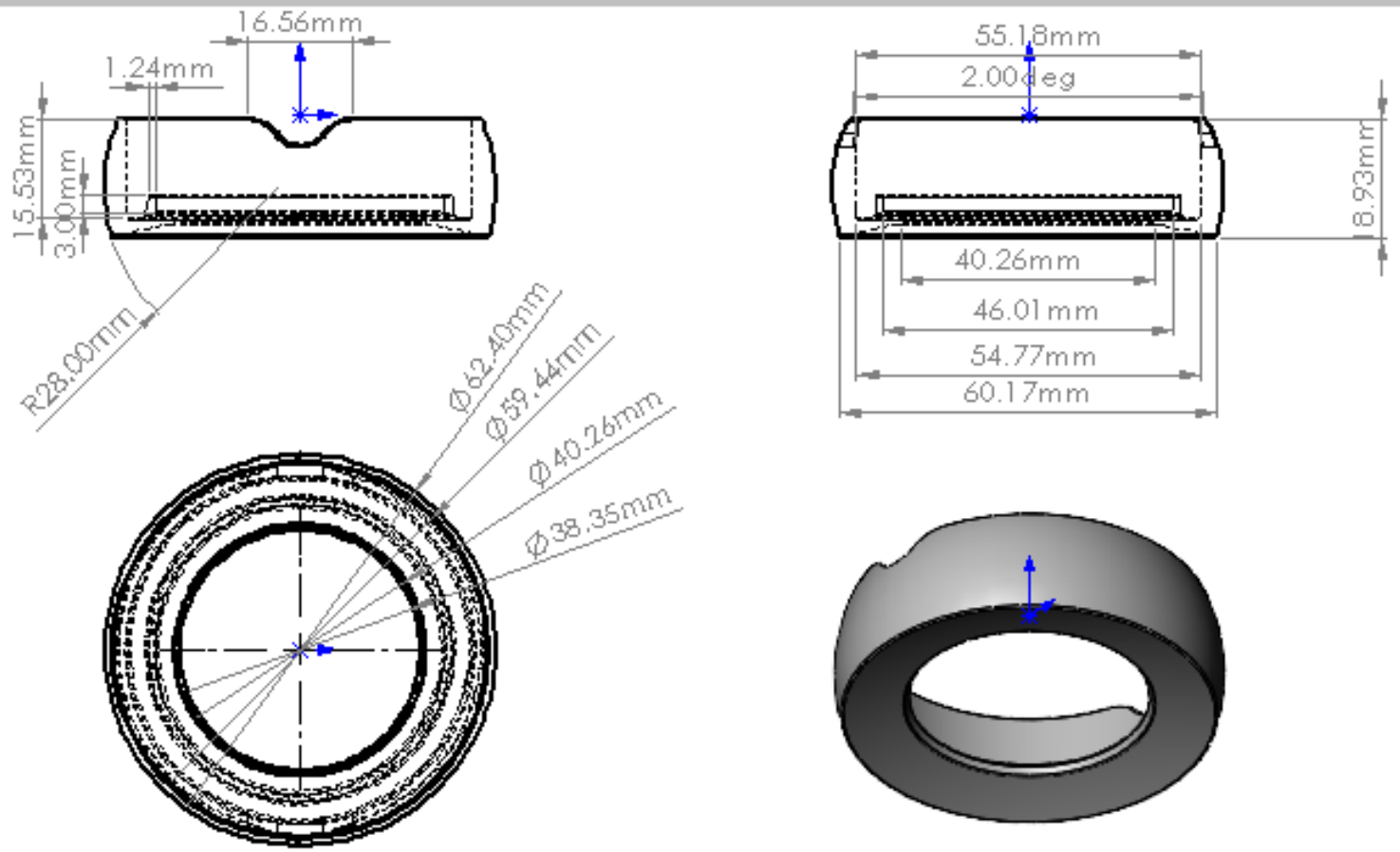
FIXED OUTER RING
SCALE: 1.1
SHEET 1 OF 1



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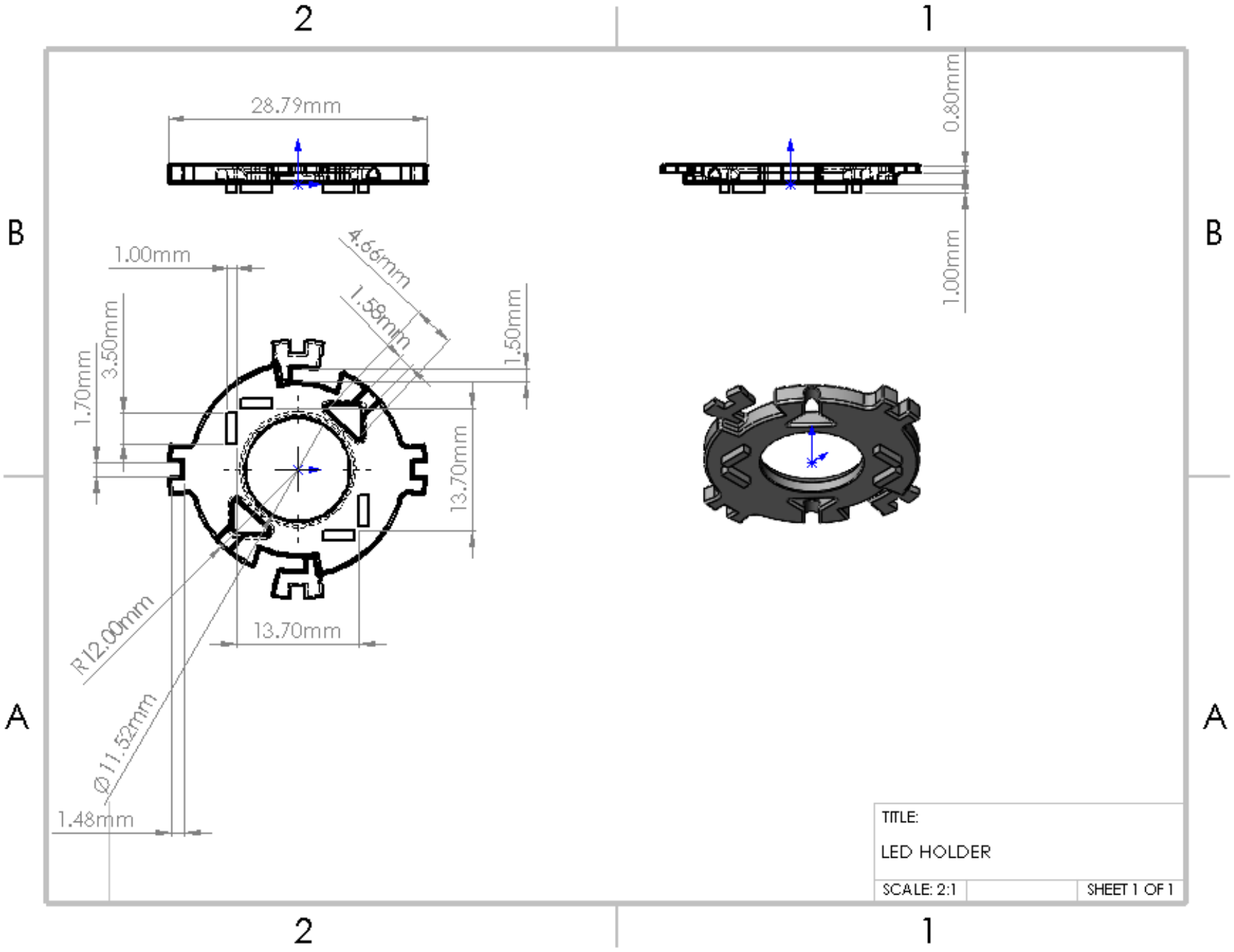
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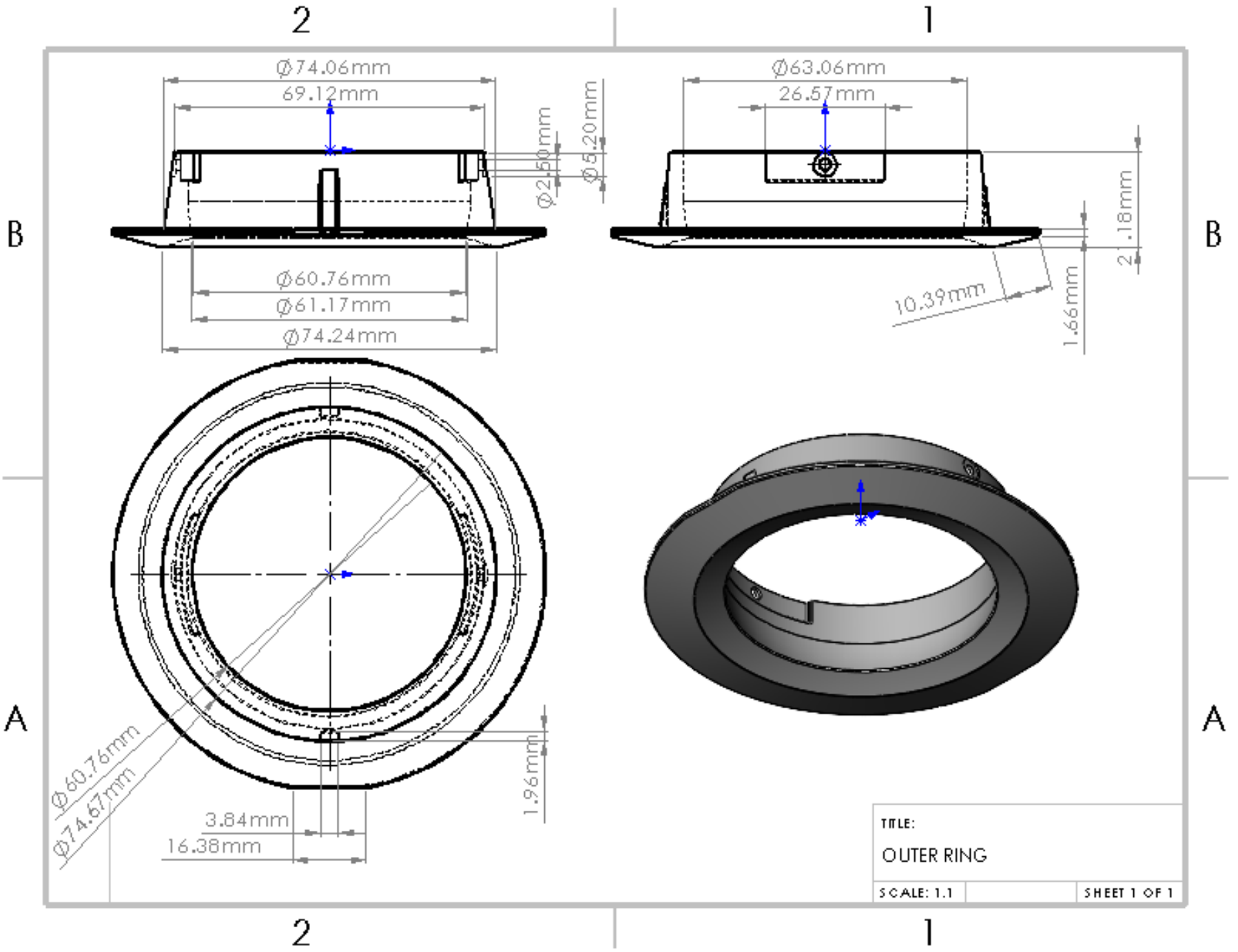
SCALE: 2:1
SHEET 1 OF 1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10.39mm
1.66mm
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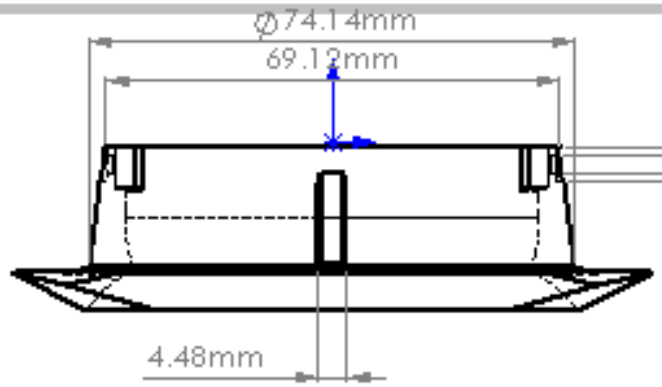
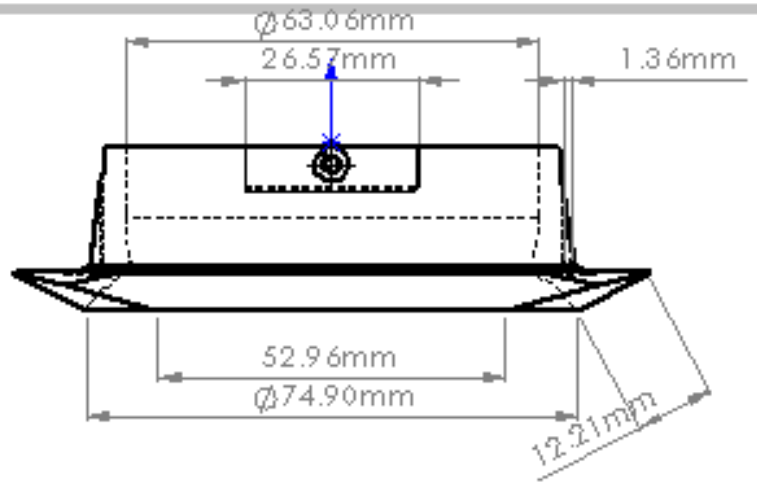
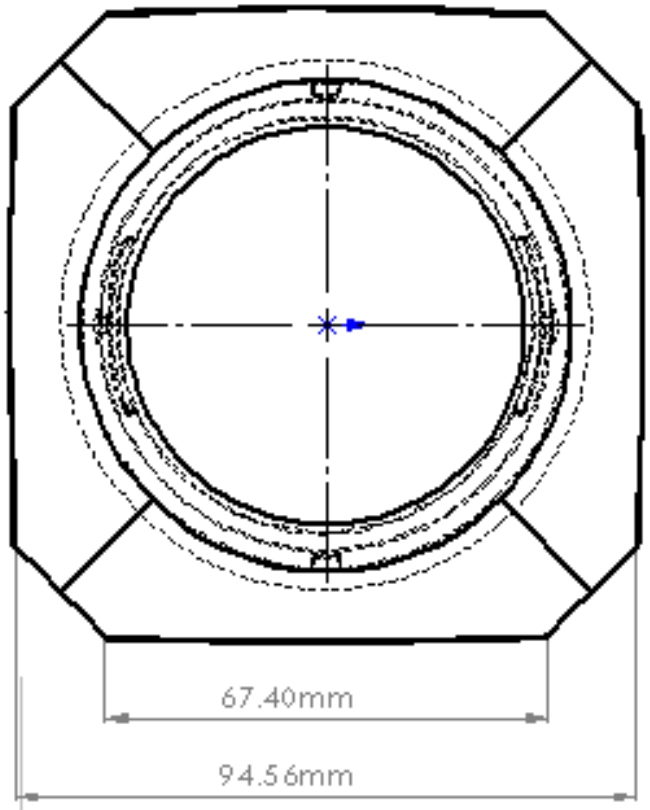
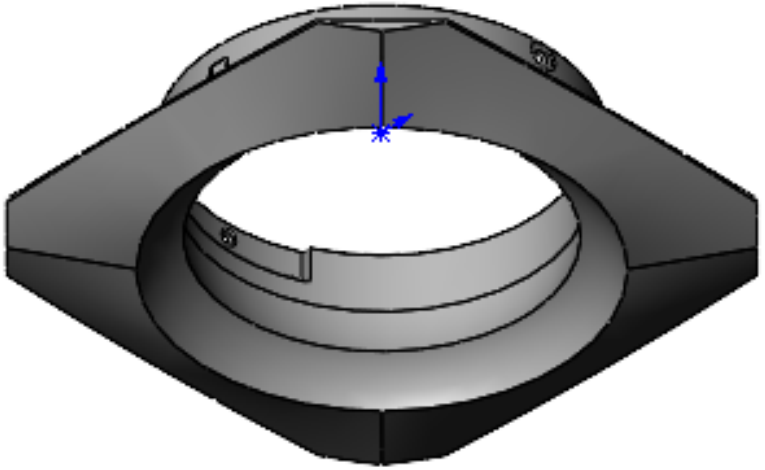
TITLE:
OUTER RING
SCALE: 1.1
SHEET 1 OF 1



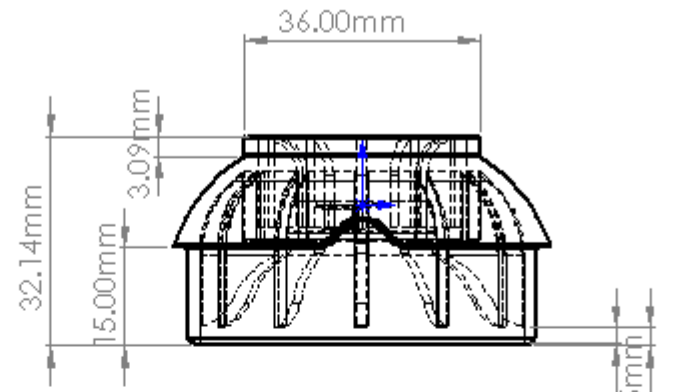


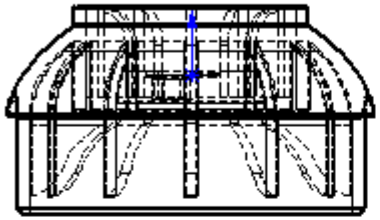


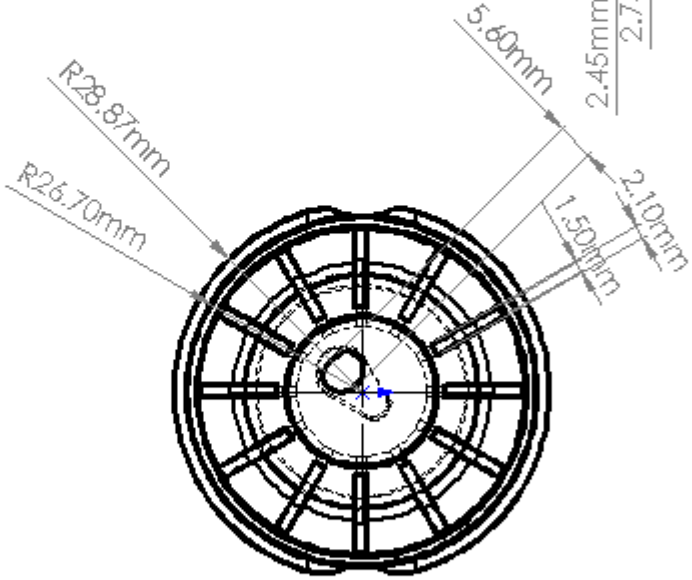


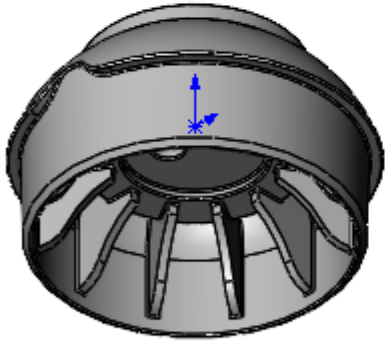
TITLE:
OUTER RING1

SCALE: 1:2 | SHEET 1 OF 1









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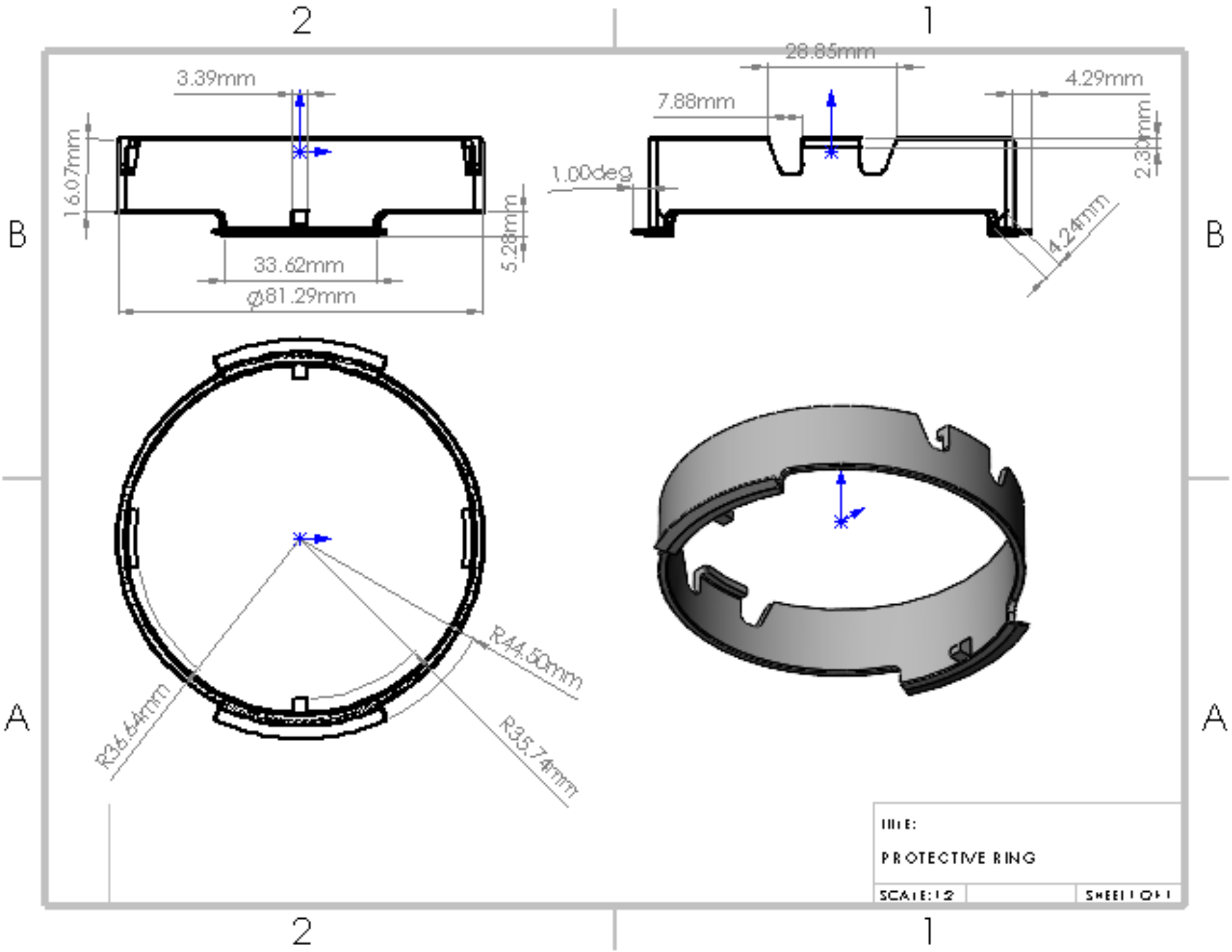
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2.30mm
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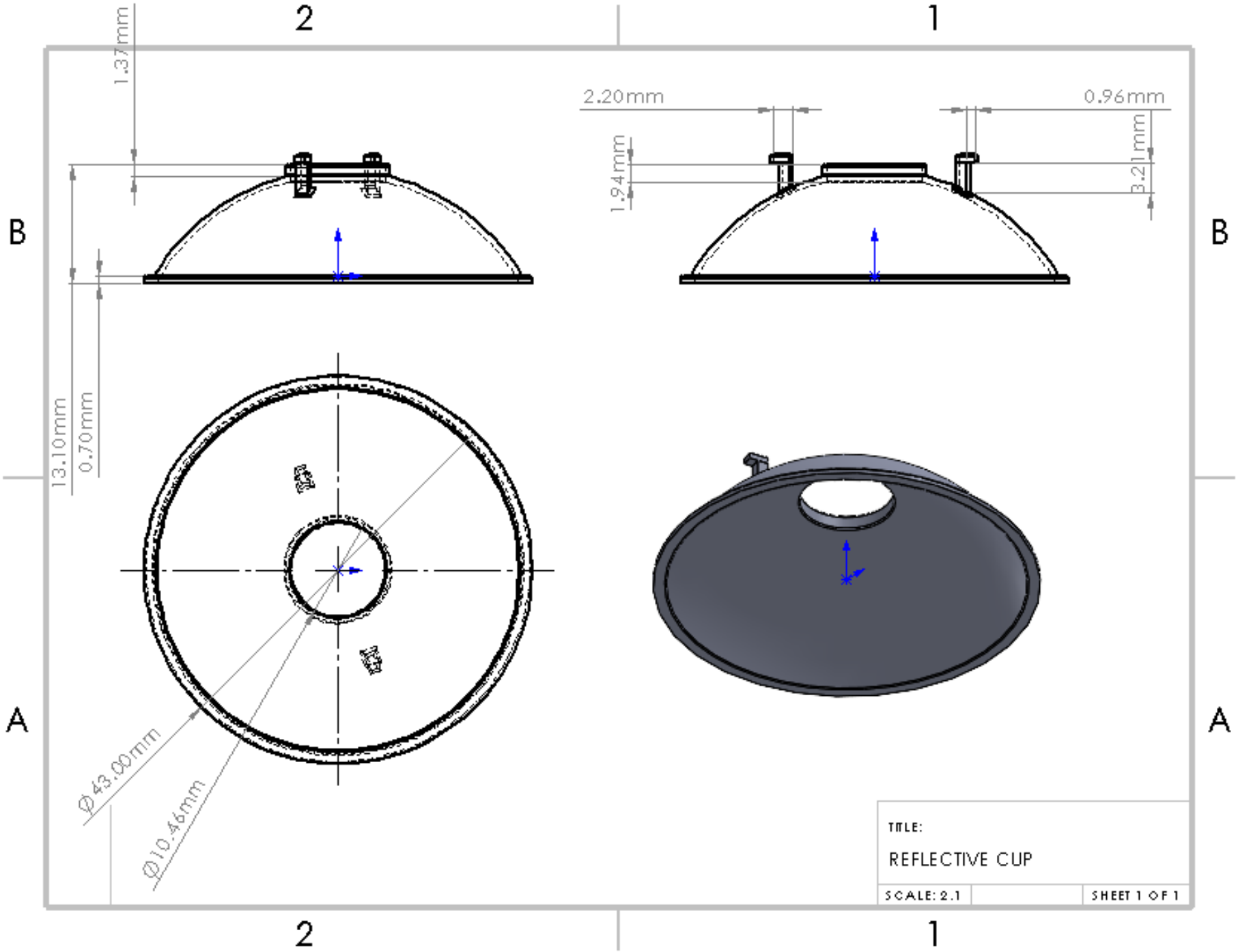
SHEET 1 OF 1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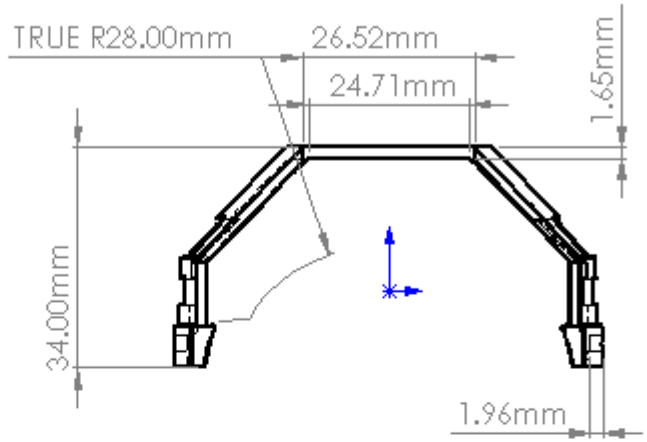
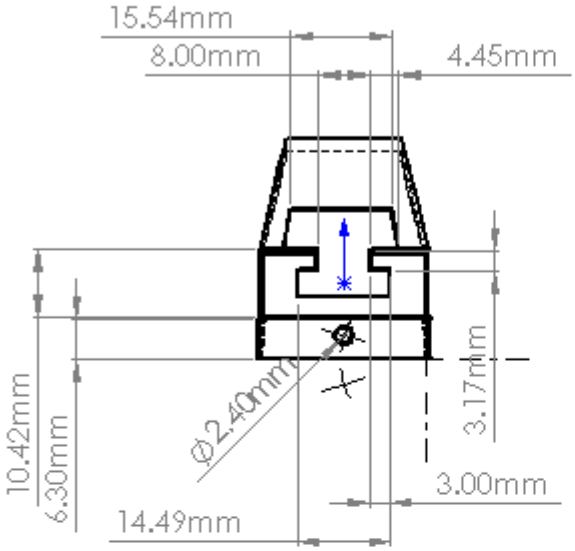
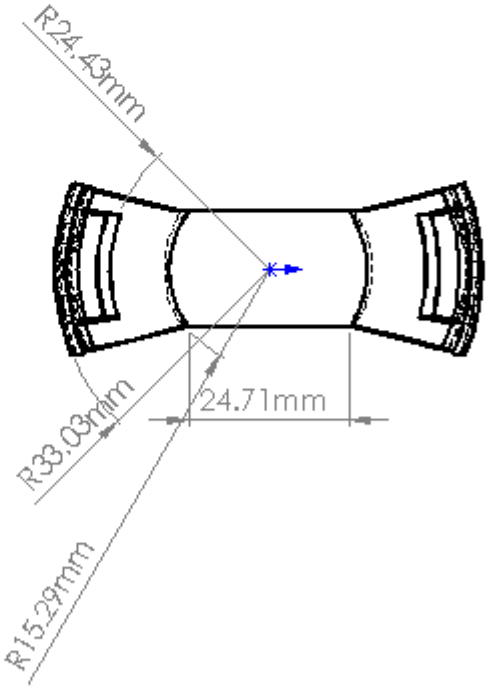
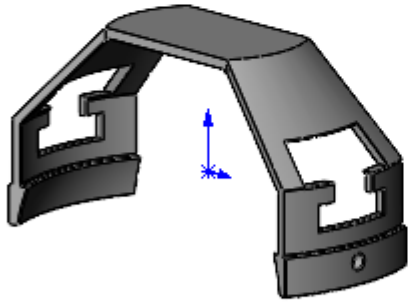
SHEET 1 OF 1









TITLE:

SPRING HOLDER

SCALE: 1:1		SHEET 1 OF 1

Feedback: This section displays the email feedback from CTM Lyng after receiving the prototype and presenting it in the Eliaden exhibition.

Terje Lillemo, CEO

"Vi i CTM Lyng er veldig glade for all den hjelp Parisa har bidratt med ift realisering av vårt prosjekt CircuLine®. Ved å ha Parisa på laget, har vi fått tanker og forslag til design, tekniske løsninger mv, som ikke ville kommet opp, om det hadde vært en forutinntatt person, som kanskje ville basert prosjektet på «vedtatte bransjestandarder og sannheter».
Vi har fått konkrete innspill til å løse oppgaven, som blir viktige i realiseringen av prosjektet, da vi erkjenner at ambisjonen og beskrivelsen var utfordrende.

Samarbeidet har gått svært bra og Parisa har levert som avtalt, på alle deadlines vi har satt, noe som kuliminerte i 3D prøver til Eliaden (31/5-2/6), som sikret at vi kunne vise frem produkter fysisk, til svært mange kunder og samarbeidspartnere, som hadde høye forventninger. Vi mener at ca 250-300 potensielle kunder fikk se prøvene disse dagene og tilbakemeldingene var udelt positive)

Med det som er gjort av arbeid i prosjektet, har vi et meget godt utgangspunkt for å realisere dette. Det vil vi gjøre."

Ståle Sund, Fabrikksjef

"Eksisterende downligts er stort sett bygd på metall, en del pga kjøling av diode, men metall er også valgt på resten av dioden. Parisa sin downligth er basert på mest mulig plast. Metallet som er igjen er nødvendig pga kjøling og mekanisk styrke, ideen med bøylen til å styre gyro og holde de mekanisk sterke fjærene er nyskapende. I et produksjonsperspektiv er det nå mulig å automatisere sammenstillingen, hvis/når man kommer opp med en annen løsning enn skruer på feste av bøylen (snap etc). En optimal sammenstilling av en downlight inneholder ikke skruer som festeanordning.

Dine løsninger begrenser ikke funksjonaliteten for brukeren, men legger produksjonsprosessene

Plast som materiale er selvfølgelig valg pga prosjektets hovedmål som var å designe en downlight i regenerert plast. Designet er på plass, løsningene er også på plass, men det jobbes fremdeles på andre fronter etter råmaterialet. Dette var ikke en del av oppgaven. Vi mener ditt utgangspunkt er noe vi kan gå videre med når vi har skaffet til veie materialet.

Konklusjonen er at vi finner produktet nyskapende, og det er en stor gevinst at flere deler kan gå igjen i flere av variantene innenfor downlight segmentet."

Vidar Løw-Owesen, CTO

Frank Robert Husby, Prosjektering

- *"Utfordrer etablerte sannheter med nye øyne og kreative løsninger.*
- *Svært interessant med mulighet for ulike fronter på et produkt (firkant og sirkel i ett produkt)*
- *Ivaretar de kvaliteter vi allerede har i produktet (NorLum Downlight) og viderefører/forbedrer de i et nytt produkt.*
- *Spennende løsning for feste av fjærklemmer.*
- *Kjøling virker å være godt ivaretatt og gjennomtenkt.*
- *Tilsynelatende meget demonteringsvennlig (reperasjon/gjennvinning)*

Potensielle utfordringer vi må jobbe videre med:

- *Byggehøyde på produktet.*
- *Fjærklemmer, dekkes de mest brukte platetykkelser ved en slik kont-struksjon?*
- *Slitasjestyrke på de elementer som utsettes for mest belastning*
- *Lysutfall og effekt, må testes"*

Parisa Ebadat

Designing of Circular LED Downlights

NTNU
Kunnskap for en bedre verden