

#### **TITLE PAGE**

#### **Project title**

Nereus - a cable cabinet

#### **Project theme**

Flooding

#### **Project team**

MSc04 - Team 5 Industrial Design Institute of Architecture and Design Aalborg University

#### **Project period**

01.02.2024 - 30.05.2024

#### **Supervisor**

Christian Tollestrup

#### **Technical supervisor**

Lars Rosgaard Jensen

#### **Number of pages**

24



Frederik Emil Larsen

Kassia Ahm

Maria Nhi Nørbye Olsen

#### **ABSTRACT**

Dette afgangsprojekt omhandler den stigende problematik med oversvømmelser i Danmark. Det præsenterer et løsningsforslag som skal hjælpe netselskaberne i Danmark med at opretholder forsyningssikkerheden under oversvømmelse. Skulle elnettet, eller mere specifikt kabelskabene, i Danmark fejle står forbrugere uden strøm og mister en essentiel ressource i deres hverdag og kamp om at beskytte deres hjem, butik, virksomhed eller lignede. Løsningsforslaget, Nereus, er udviklet i samarbejde med netselskaberne Trefor og N1 samt deres el montører. I dag er netselskabernes eneste løsning at koble skabene fra ellers risikere de kortslutninger. Dette efterlader forbrugere uden strøm indtil en montør har været ude og vurdere hvorvidt der er sket skade. Er uheldet ude, skal skabet erstattes og den eneste forebygning der kan laves for det sker ikke igen er at hæve skabet.

Derudover har der gennem projektet været sparring med Triarca der producere kabelskabe samt stadsarkitekter i Danmark for at tilpasse deres udtryk til byrummets æstetik.

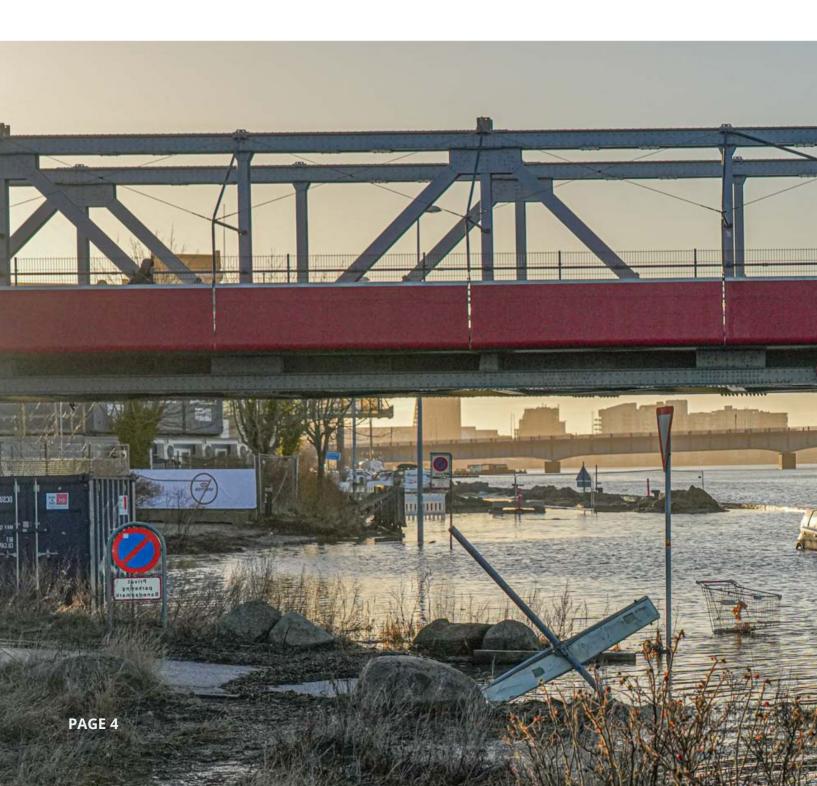
Sammen med disse interessenter er løsningsforslaget Nereus blevet udarbejdet. Nereus er et redesign af det traditionelle kabelskab specielt lavet til at modstå oversvømmelser nu og i fremtiden. Ved at lave et lufttæt kammer i den øvre halvdel af skabet, forhindre Nereus vand i at trænge op til de komponenter i skabet der sikrer elnettet operer som ønsket. En egenskab som elmontørerne intuitivt og nemt kan aktivere takket være de to kompresionslåse der udnytter deres kendte trekantslås system. Låsene holder frontdøren tæt ind mod pakningen, hvilket skaber en forsegling rundt langs kanten og beskytter skabet.

#### **Content**

5	More water, more problems	18	Components
8	Nereus	22	Business Case
10	Sealing	22	Implimentation
16	Packaging	24	Variants
17	Assembly		



Our world is changing, and the consequences are hitting us closer to home than ever before. In October of 2023, Denmark was hit with an incident of flooding, the **biggest incident** in more than 100 years, and this level of severity is going to become more frequent.

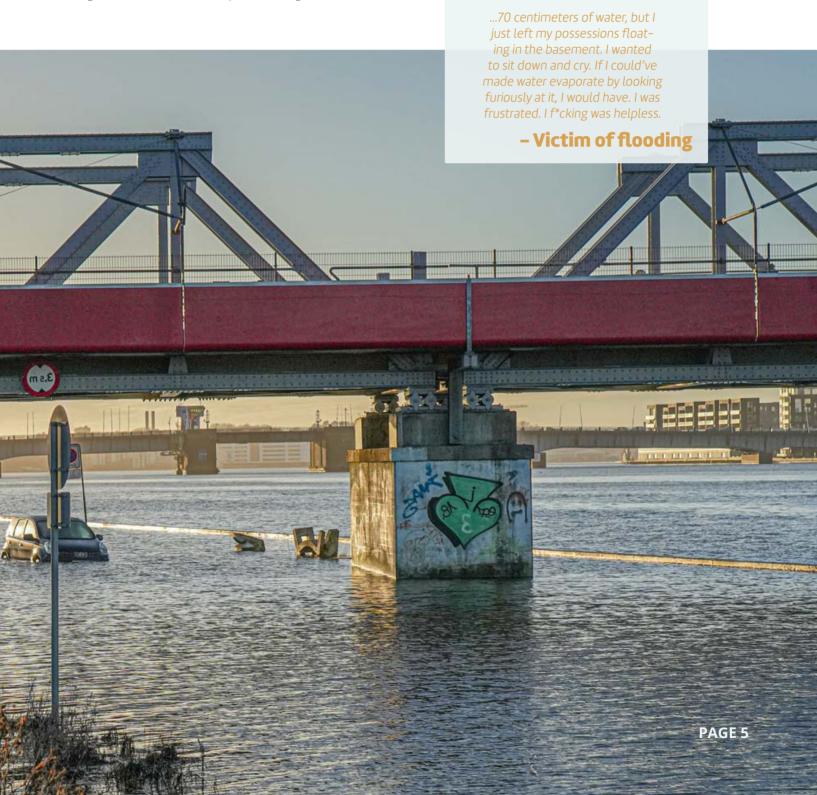


#### More water, more problems

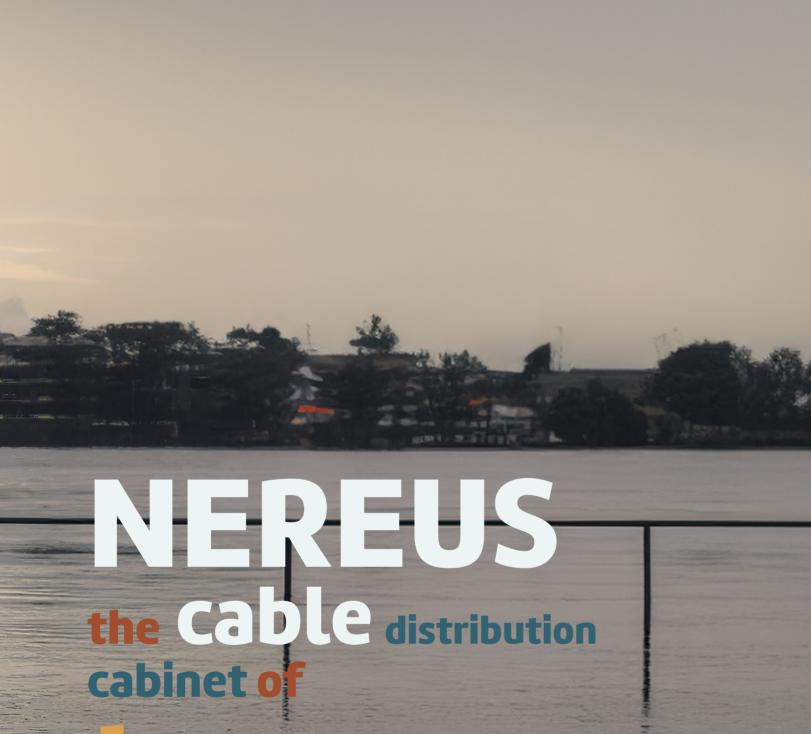
The future points to more water invading our streets. When the urban environment and national initiatives fail to keep the threat at bay, the fight is brought directly upon our doorstep. We protect our homes, our families, to the best of our abilities. Barriers to keep the water out, pumps to fight the amount that makes it in regardless. Life goes on inside, but when the pumps fail, the lights go out and the heater stops, life changes for a moment.

Your local Cable Distribution Cabinet has malfunctioned due to the water, disconnecting you from the power grid. You've lost power. You've lost the ability to fight for your

home. You've lost agency!







abinet of COMMON COMPON COMPON



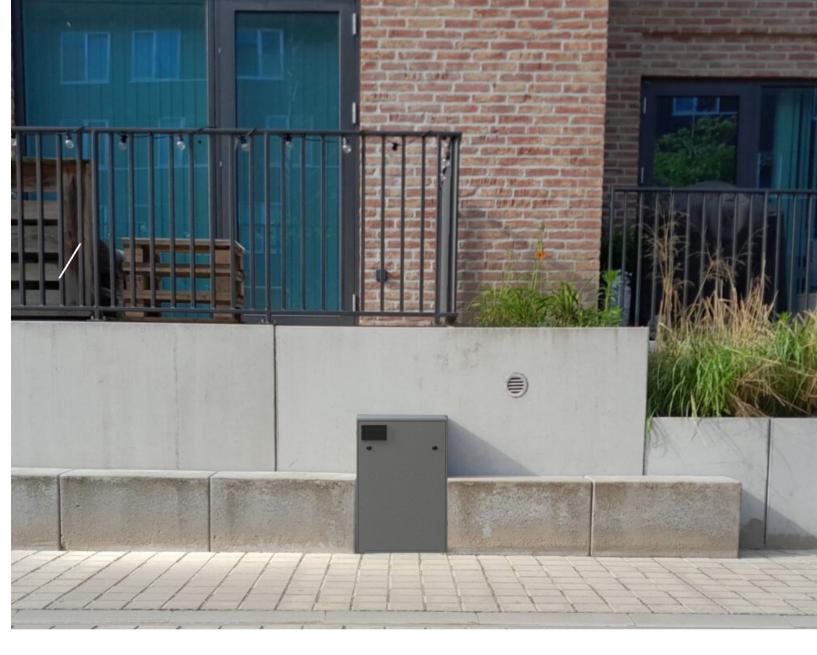
### **NEREUS**

the cable distribution cabinet of tomorrow

If the loss of power during a flooding is the pain, then Nereus is the cure. Getting what you pay for when you need it the most, this Cable Distribution Cabinet of the future allows you to stay powered on through the whole incident.

Some people get disconnected from the power grid as a pre-emptive measure by their local Distribution Company, while others fall victim to the nearby CDC short-circuiting as water slips in through the cracks.

With Nereus, neither becomes reality.



## **Physics is**

and simplicity is key. Nereus utilizes a simple, scientific principle for a reliable result under every incident. Every

> Go grab a glass. Turn it on its head and put it into water. Feeling how it wants to push itself upwards? Don't let it.

Like with your glass, Nereus is open at its bottom. Counterintuitively, perhaps, this gives Nereus the ability to keep water out, being a bulwark against the forces of nature.





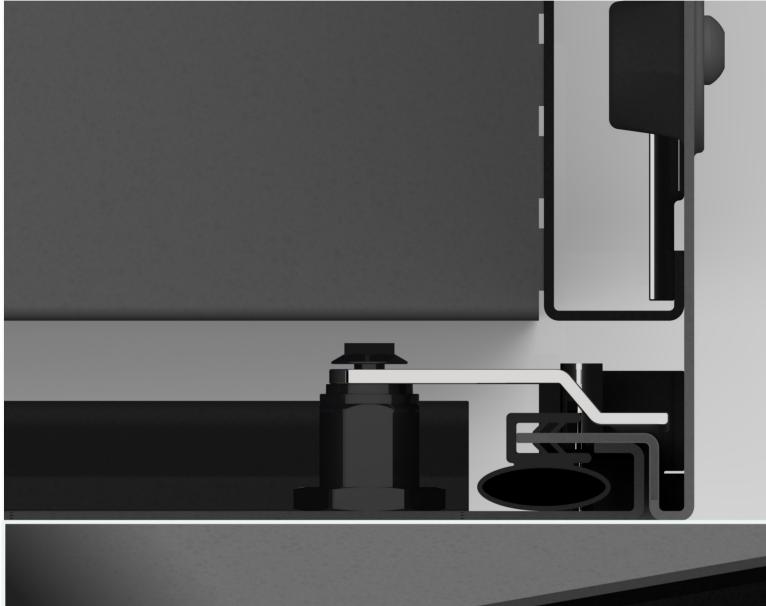
## Sealing

As an incident threatens to force the hand of the Distribution Company to disable the power grid under normal circumstances, there is nothing to fear when Nereus is deployed. Unlike the regular CDC's, Nereus embraces the water, to an extent, and uses its force against itself. Usually, for water to enter a space, it needs to replace the volume of air already present. Nereus, acting like an airtight chamber, gives the air no exits to escape through. Except for the bottom, the exact place the water is trying to enter. As the two forces meet, they keep each other at bay.

Contrasting an upside-down glass, Nereus needs a way for the maintenance responsible, the Fitter, to enter. The secret for Nereus to create its airtight chamber is the delicate balance between its seal and the compression. When the Fitter interacts with Nereus, it is crucial to its credibility that it is closed the same way, with the same level om compression every time, to spare the delicate seal of unnecessary wear and tear.

#### Nereus is designed to help the Fitter maintain its effectiveness.

When Nereus is closed by the Fitter, they cannot over-compress the seal, thanks to the intentional dimensioning of the door. By making the door connect with the base, the Fitter receives a clear, tactile signal that Nereus has been sealed enough and correctly.







By only having one point of entry, with a singular sealing, the possibility of making a mistake is reduced

Nereus is dependent on applying uniform pressure along the area of the sealing gasket. This pressure is applied through the door, facilitated through two compression locks at the top and an interlocking point at the front panel.

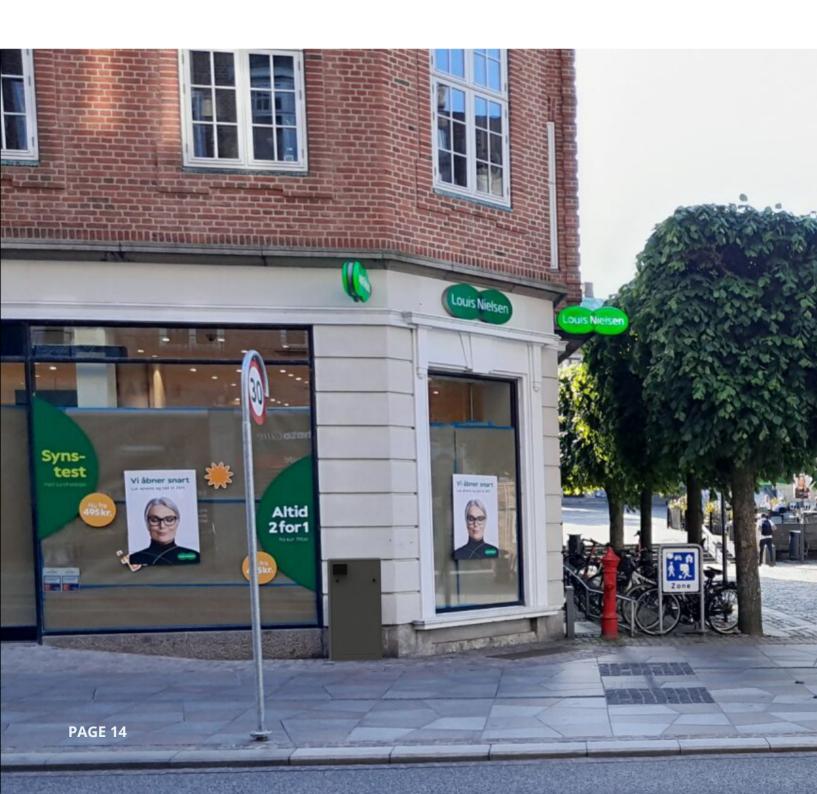
When closing Nereus, the interlocking point is placed to the top of the front panel.

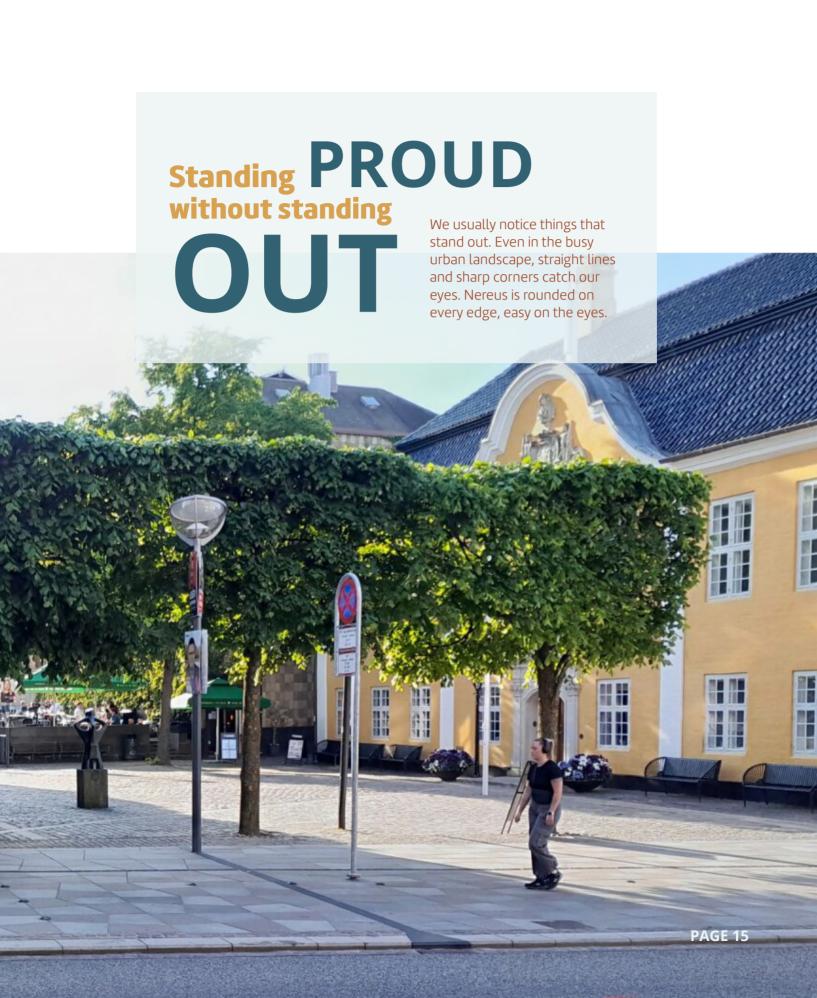
As the door is tilted inward, the angled connection between door and panel begins to create pressure.

Once the door is tilted in, it can be secured by the Fitter through the two compression locks.

These three points create enough compression on the sealing gasket to ensure the function of Nereus.

The best way to hide is to blend in and Nereus is designed to be invisible. Well, not completely invisible, but just like trouble, you will only find it if you go looking for it.

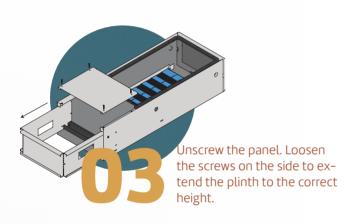


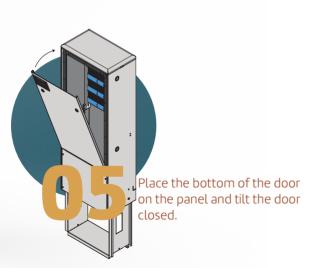


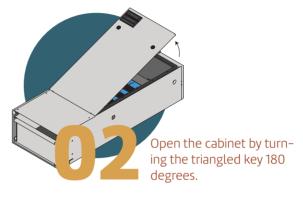


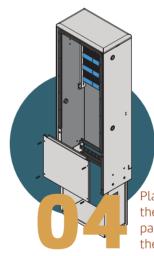


# **Assembly**Guide

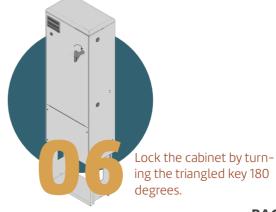








Place the cabinet and ensure the cabinet is level. Push the panel into place and fasten the screws.



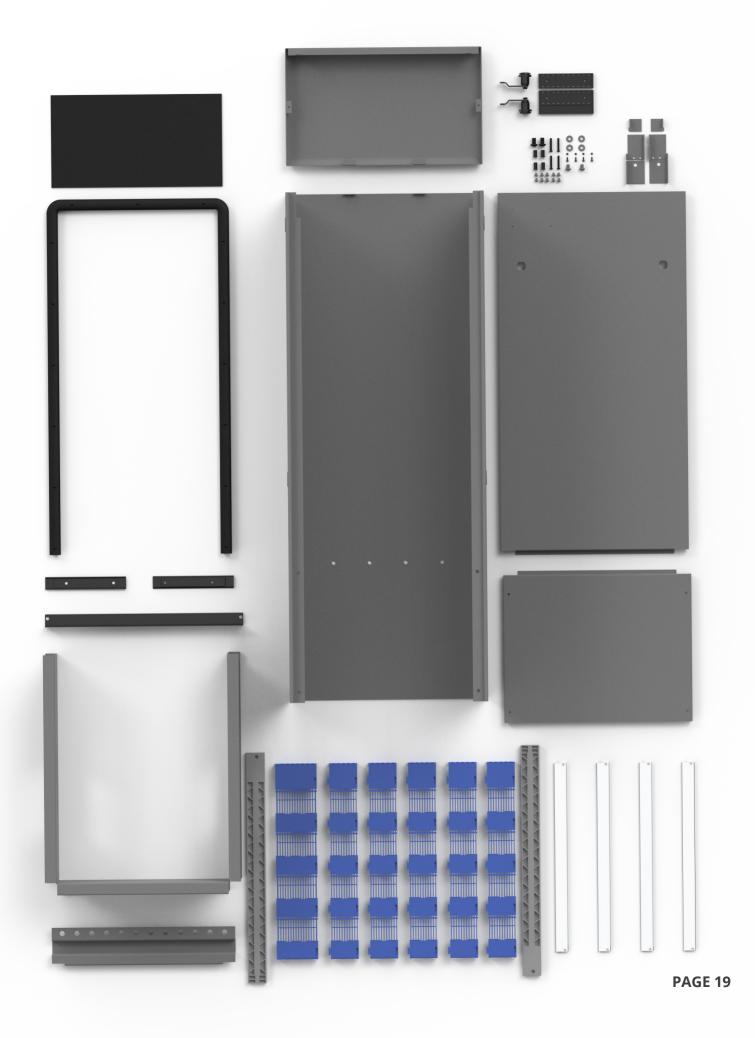
## **Data Sheet**

#### **Materials**

Base	Aluminum
Front door	Aluminum
Panel	Aluminum
Brace	Stainless steel
Plinth	Aluminum
Rubber gasket	EPDM celullar rubber

#### **General Specifications**

Weight	17,2 kg
Depth	280 mm
Width	466 mm
Height	1200 mm
Height above ground lvl.	900 mm
Height of plinth	566 mm
Airtight	Yes
Coating	Rilsan



## **Business Case**

Nereus is designed as an alternative cable distribution cabinet for the distribution companies It adresses their increasing problem of flooding tribution cabinet for the distribution companies. It adresses their increasing problem of flooding which. A problem which is unpredictable and has great consequences. Finacially and for the aspiration of maintaing 100% power supply for the consumer.

#### **Value proposition**

To provide waterproof cabinets that ensure a reliable power supply during flooding.

Nereus' production cost is 4331,9 DKK pr unit. With bought materials and outsourced production and coating the cost is only covering the variable costs. It is sold directly to the distribution companies depending on their demand for floodproof cabinets. The market today consists of 1.1 million CDCs with an estimated 16.5% in a risk zone. Sold at 14.000 DKK, Nereus is priced higher than the existing cable distribution cabinet but offers a lower total cost of ownership during its 50-year lifespan.

Sales price: 14.000 DKK

Production: 4331,9 DKK

Number of CDC's in Denmark: 1.100.000

Exposed cabinets 16.5% variable costs. It is sold directly to the distribution companies



#### **Stakeholders**

Besides providing the distribution companies with a product that solves their problem of flooding. Nereus provides value for each stakeholder in a different way whether it be function, aesthetics or interaction.

**The electrical fitter:** Employed by the distribution companies to maintain, replace and install cable distribution cabinets. They are the users of the product and affected by changes to the interface,

The city architects: A public employee whose responsibility is to ensure a coherent and architectural vision for the urban environment. They are primarily interested in the aesthetic of the product and a design that diruspts the urban environment minimally.

**The citizens:** The people dependent on the functionality of the CDC's. Without, they lose electricity, a key resource in modern society and a critical tool for protecting their belongings, businesses and homes from flooding.

#### The Vision / Mission

The aspiration behind the Nereus cabinets is rooted in a desire, and a responsibility, of partaking in the protection and operation of the power infrastructure. With a goal of influencing the outcome, when nature forces itself into our house, Nereus secures a life essential resource, when disaster could occur.



## Implimentation



#### 1: Product maturation

A product maturation process is initiated where 1:1 prototype are built to test interaction and achieve proof-of-concept.

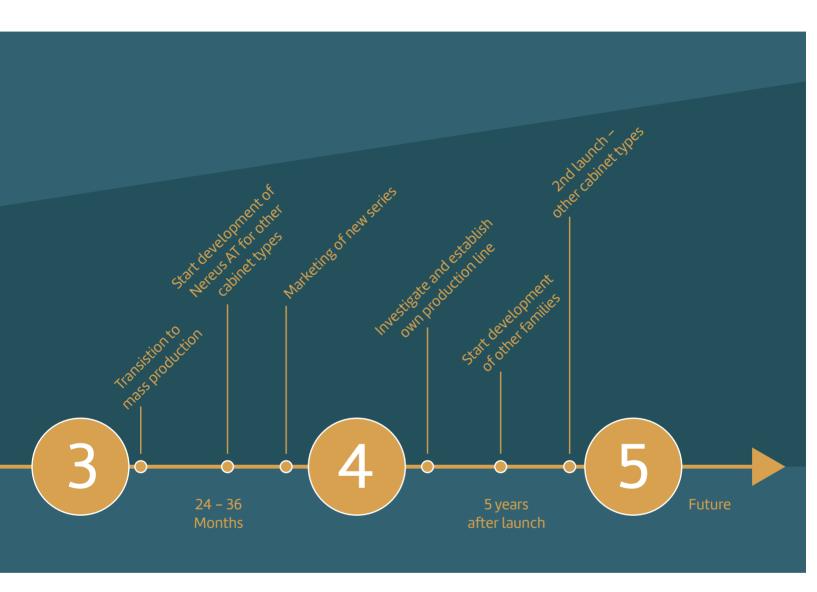
Meanwhile the Nereus AT-series is developed while further market investigation is conducted.

#### 2: 0-Series

Final agreements are settled with suppliers and manufacturers providing a steady flow of goods while tests are conducted before achieving necessary certification. A 0-series is produced to help promote the product while developing the sales channels.

#### 3: Product launch

The Nereus AT-series is launched and sold to distribution companies. In the aftermath proof-of-scale is confirmed to determine the necessary steps before mass production is initiated. The possibility of developing Nereus AT for different cabinets owners is initiated.



#### 4:Mass production & scale

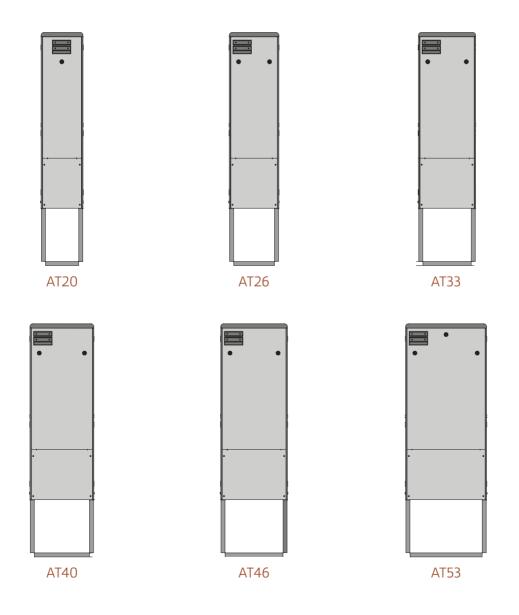
One year after launching the transition towards mass production is initiated. Meanwhile the development of Nereus for other cabinet types is ongoing to expand towards new markets.

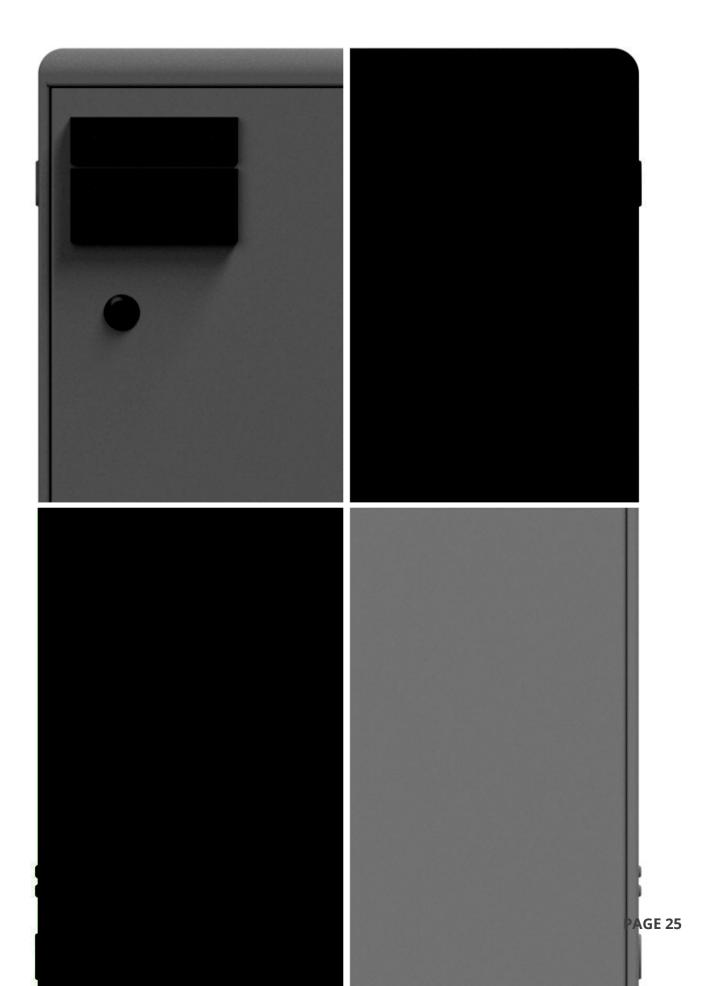
#### 5: Establishing a portfolio

2–3 years after launch a 2nd launch aimed at different cabinet owners (gas, TV, internet, etc) is made. The sales channels are expanded to include B2C retailers to accommodate for increased market size. Development of a new product series aimed at different use scenarios is started, while the possibility of expanding international is investigated.

## **Variants**

Not only the Distribution Companies require future–proof solutions. Looking at the market today, a variety of cabinets exist, differing in size, style and purpose. Their common denominator is the need to keep water out. In the future, varieties of the Nereus cabinet line will enter the market to bring a security of supply to every trade While existing product–series, such as the airtight, Nereus AT, will be dimensionally expanded upon







# NEREUS CABINET

**TECHNICAL DRAWINGS MA4-ID5 JUNE 2024** 

#### **Project title**

Nereus - a cable cabinet

#### **Project theme**

Flooding

#### **Project team**

MSc04 - Team 5 Industrial Design Institute of Architecture and Design Aalborg University

#### **Project period**

01 02 2024 - 30 05 2024

#### **Supervisor**

Christian Tollestrup

#### **Technical supervisor**

Lars Rosgaard Jensen

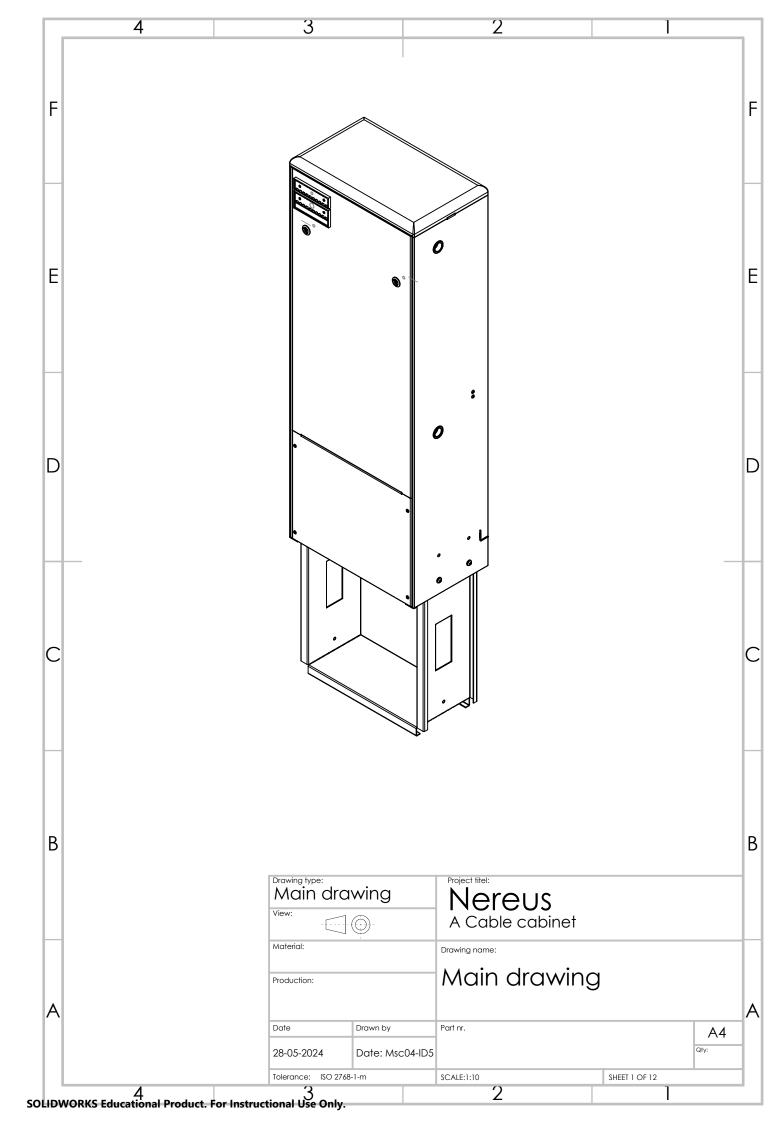
#### **Number of pages**

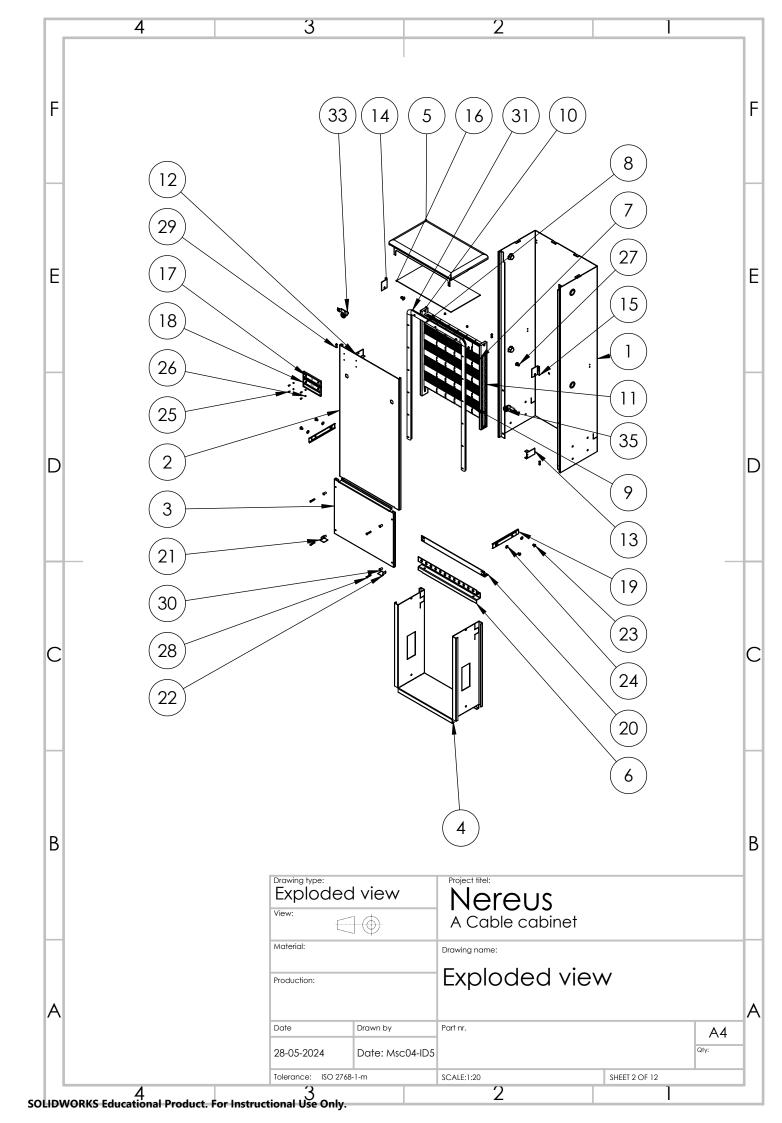
12

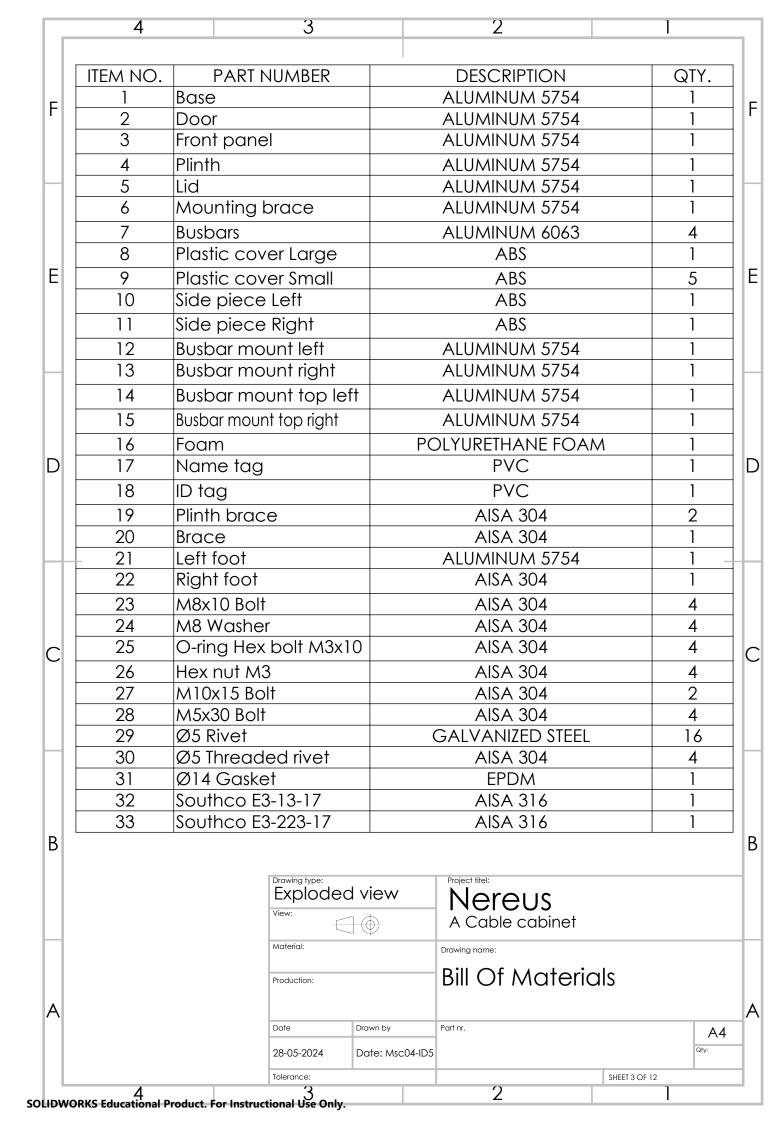
#### Content

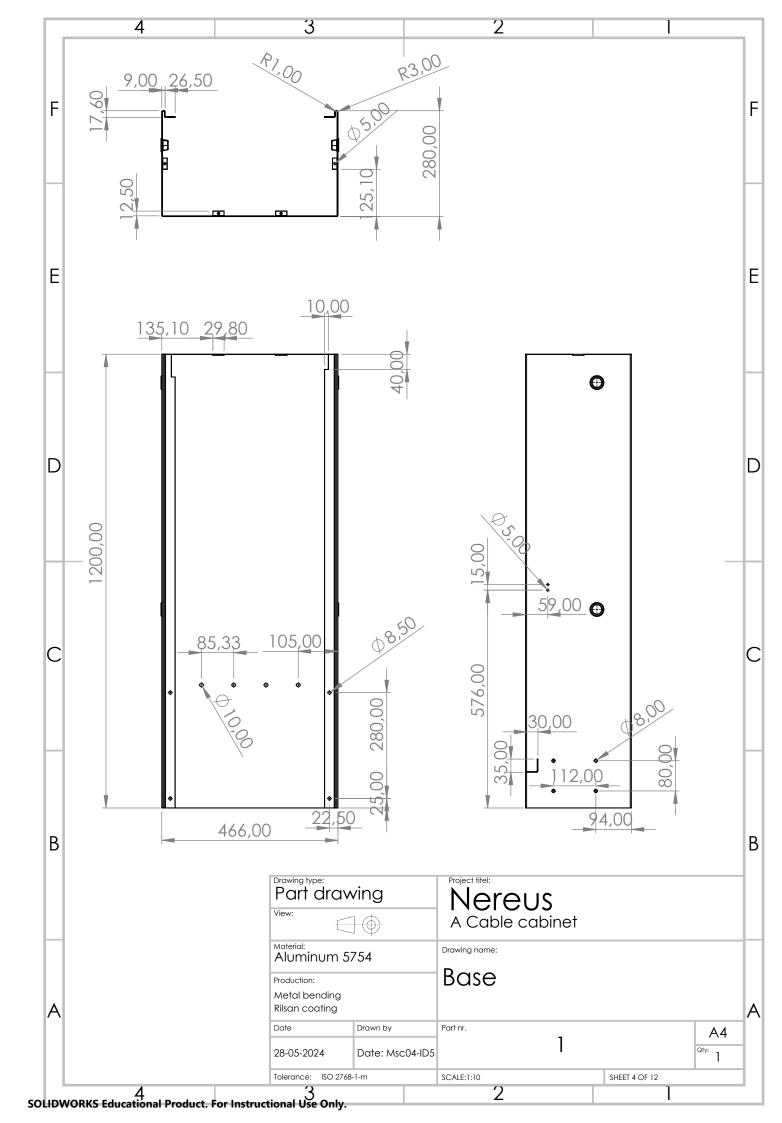
- 1. Main drawing
- Exploded view
- 3. BoN
- 4. Base
- 5. Base Sheet
- 6. Door
- 7. Door Sheet
- 8. Front panel
- Front panel Sheet
- 10. Plinth
- 11. Plinth Sheet
- 12 Lid

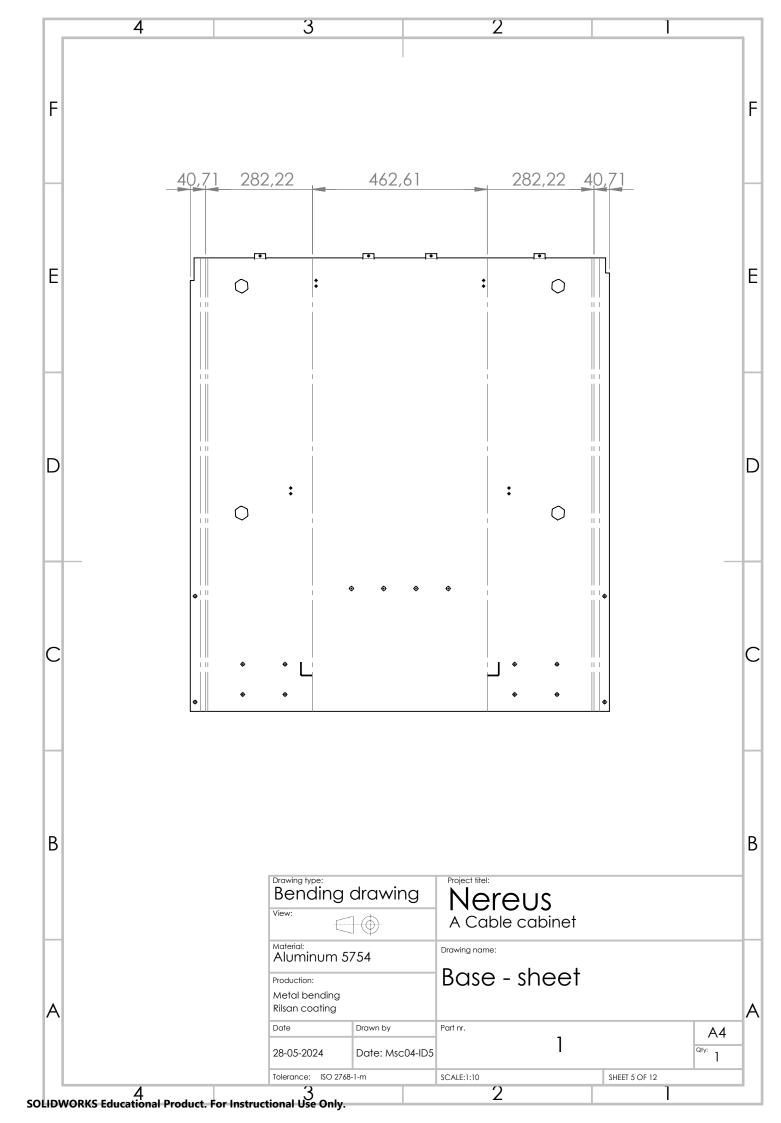


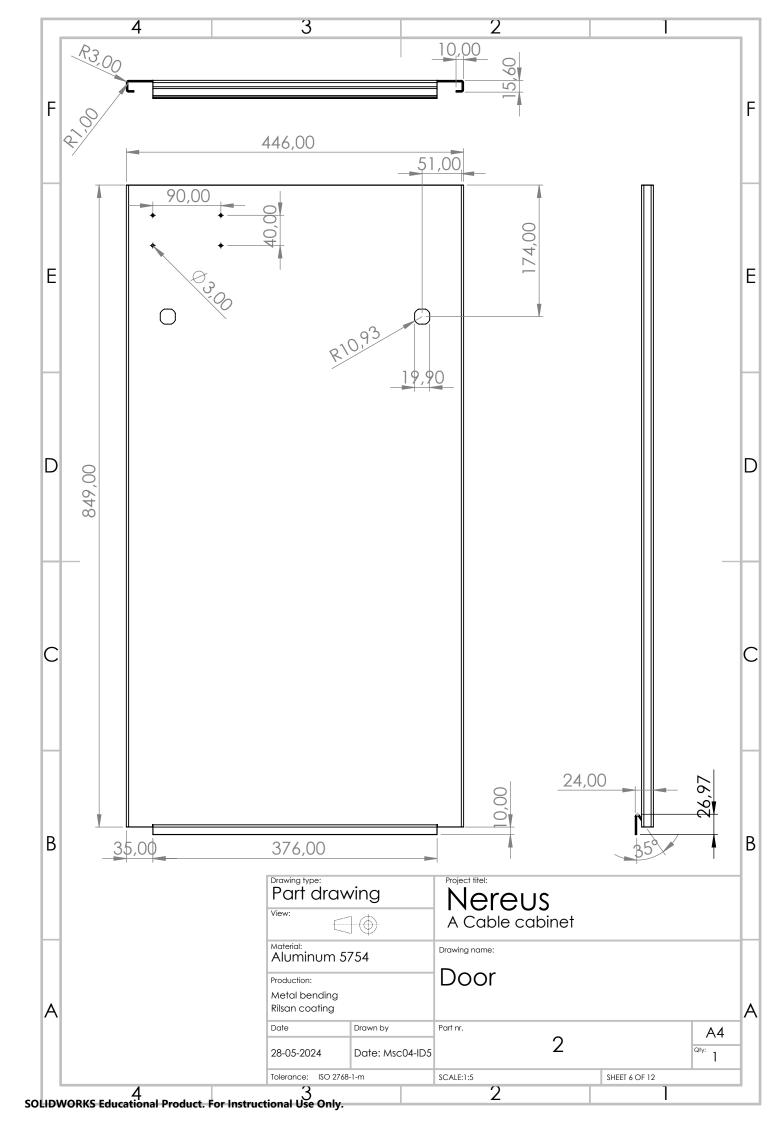


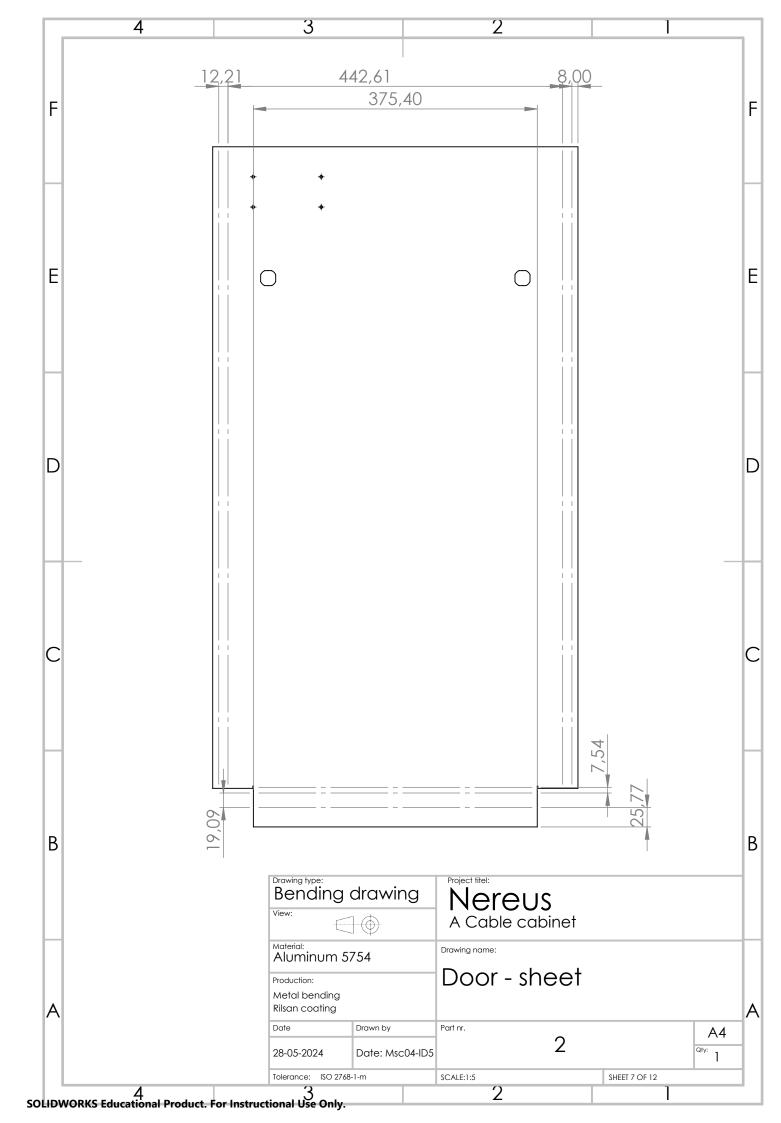


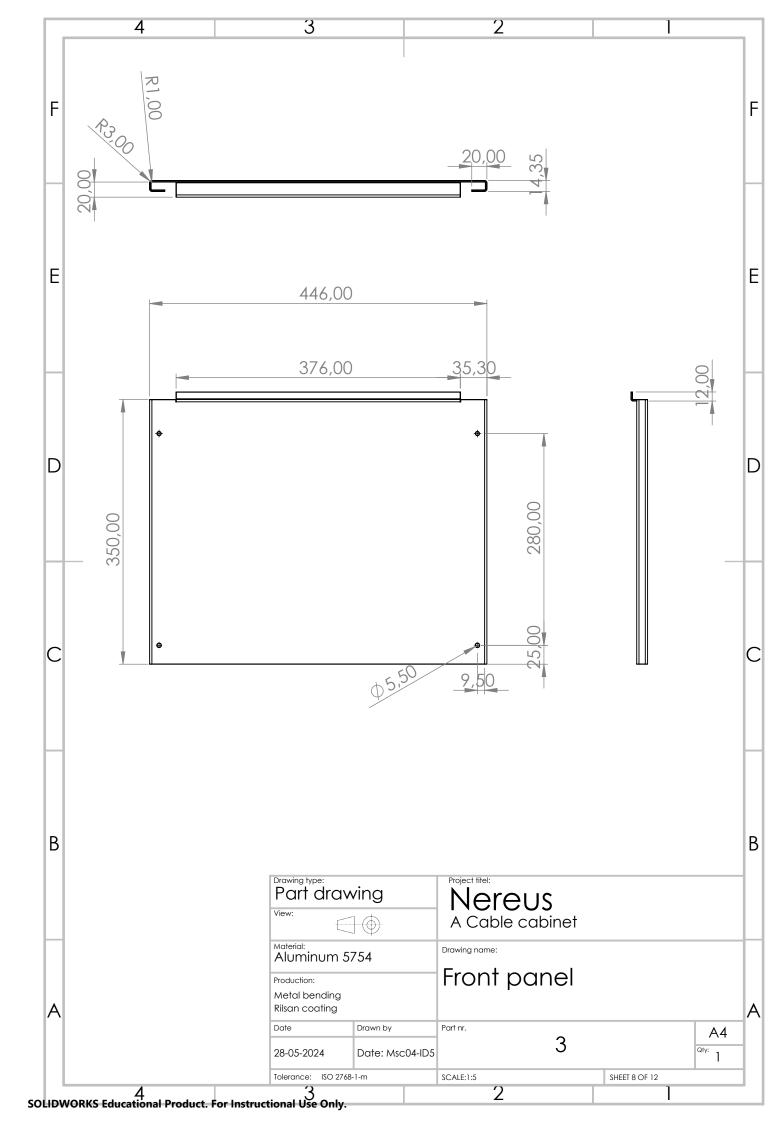


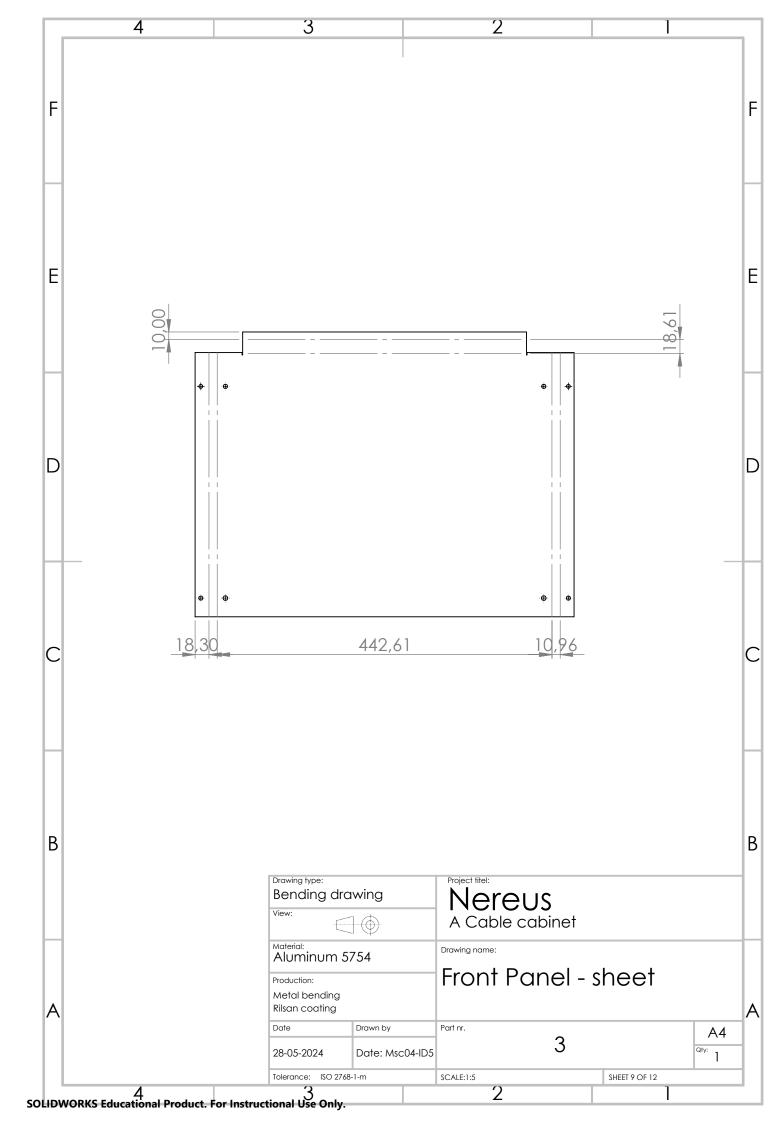


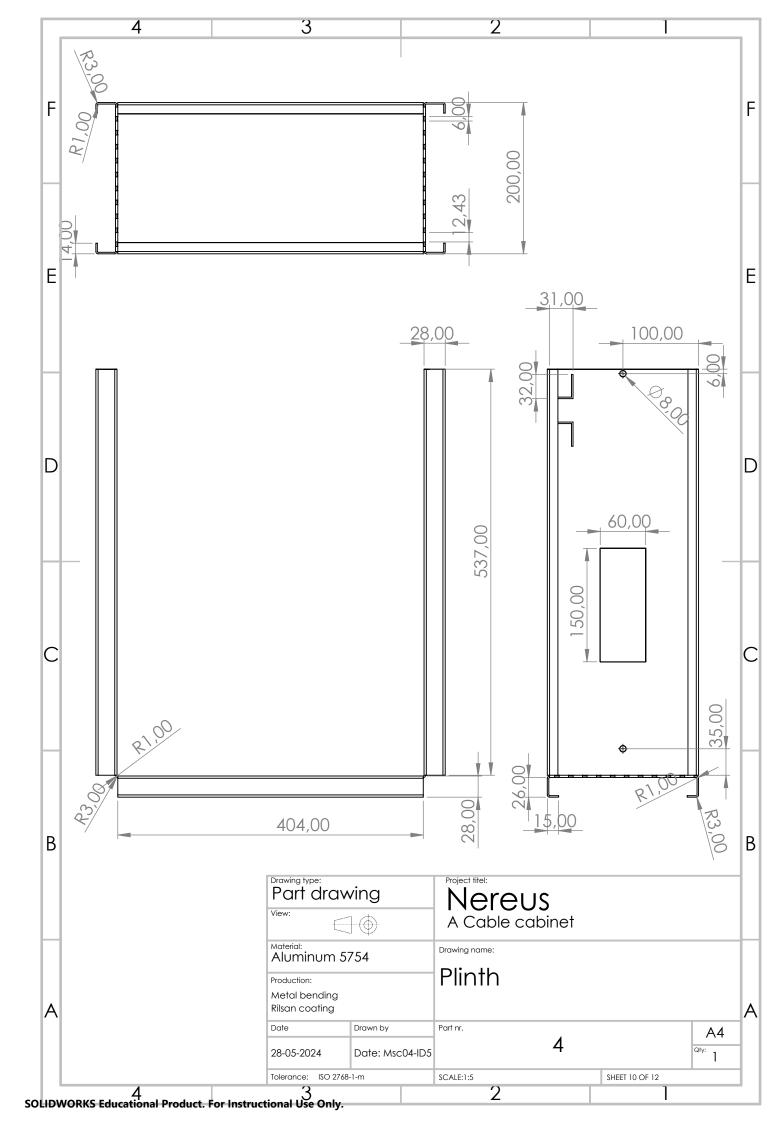


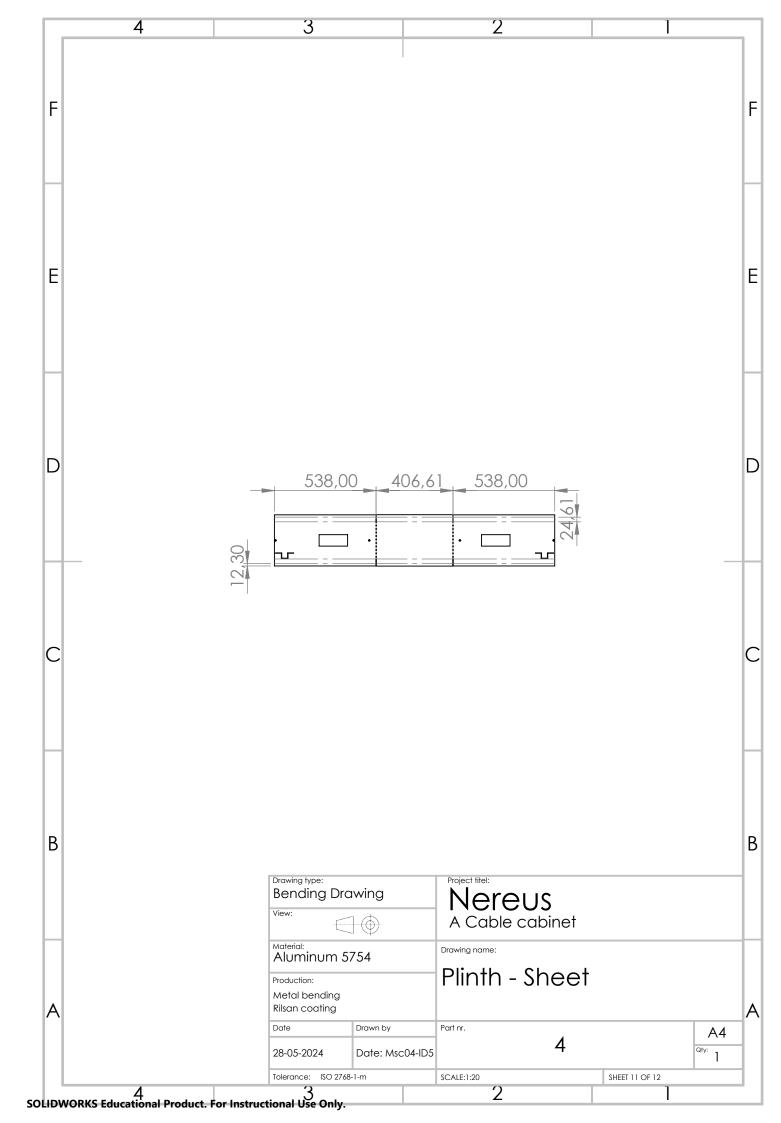


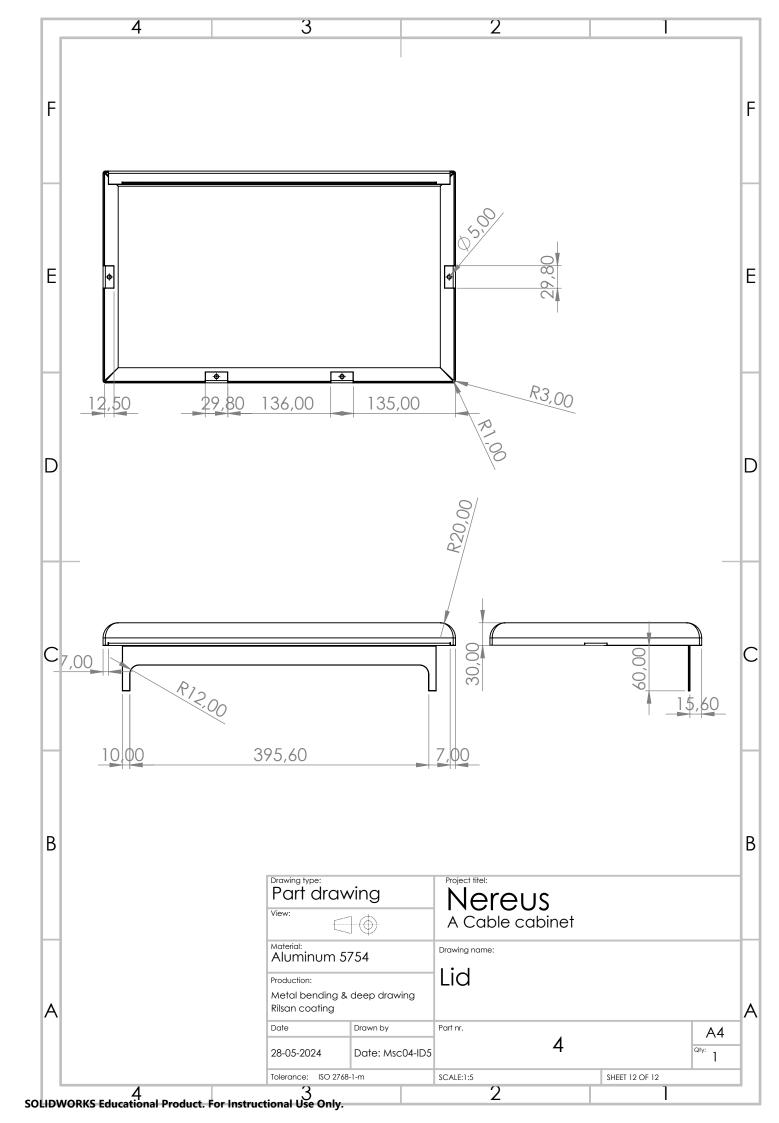






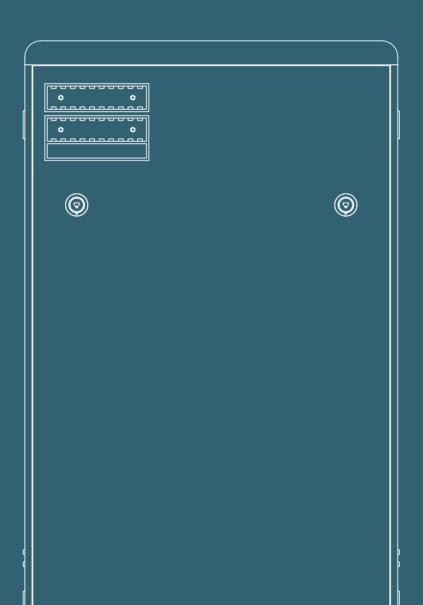






# NEREUS CABINET

PRODUCT REPORT MA4-ID5 JUNE 2024



# **TITLE PAGE**

# **Project title**

Nereus – a cable cabinet

# **Project theme**

Flooding

### **Project team**

MSc04 - Team 5 Industrial Design Institute of Architecture and Design Aalborg University

# **Project period**

01 02 2024 - 30 05 2024

# Supervisor

Christian Tollestrup

# **Technical supervisor**

Lars Rosgaard Jensen

# **Number of pages**

107

# **Appendix**

37



llustration 1: The team

### **Our Motivation**

We, as Industrial Designers, are in part responsible for shaping the products of tomorrow. Through our skills, through our empathy and through our ability to place something real, meaningful and tangible in the world to make a difference. We stand at the brink of receiving our titles and facing a new challenge; presenting ourselves to the world through our achievements. When observing a societal problem of flooding, we therefore felt the need to intervene.

Sexy end results sell. Is this project sexy? No, however, neither is the problem at hand nor the hardships of victims of flooding. This solution is a necessity. It is empathy.

In a world full of change, we must step up and take responsibility for the people in it. As Industrial Designers, that is our motivation.

Frederik Emil Larsen	Kassia Ahm	Maria Nhi Nørbye Olsen

# **ABSTRACT**

Dette afgangsprojekt omhandler den stigende problematik med oversvømmelser i Danmark. Det præsenterer et løsningsforslag, som skal hjælpe netselskaberne i Danmark med at opretholde forsyningssikkerheden under en oversvømmelse. Skulle elnettet, eller mere specifikt kabelskabene, i Danmark fejle, står forbrugeren uden strøm og mister en essentiel ressource i deres hverdag og kamp om at beskytte deres hjem, butik, virksomhed eller lignende.

Løsningsforslaget, Nereus, er udviklet i samarbejde med netselskaberne Trefor og N1, samt deres el-montører. I dag er netselskabernes eneste løsning at koble skabene fra ellers risikere kortslutninger. Dette efterlader forbrugeren uden strøm indtil en montør har været ude og vurdere, hvorvidt der er sket skade. Er uheldet ude, skal skabet erstattes og den eneste forebygning, der kan laves for, at det sker ikke igen, er at hæve skabet.

Derudover har der gennem projektet været sparring med Triarca, der producerer kabelskabe, samt stadsarkitekter i Danmark, for at tilpasse deres udtryk til byrummets æstetik.

Sammen med disse interessenter er løsningsforslaget Nereus blevet udarbejdet. Nereus er et redesign af det traditionelle kabelskab, specielt lavet til at modstå oversvømmelser nu og i fremtiden. Ved at lave et lufttæt kammer i den øvre halvdel af skabet, forhindre Nereus vand i at trænge op til de komponenter i skabet, der sikrer at elnettet, opererer som ønsket. En egenskab som elmontørerne intuitivt og nemt kan aktivere, takket være de to kompresionslåse, der udnytter deres kendte trekantslås-system. Låsene holder frontdøren tæt ind mod pakningen, hvilket skaber en forsegling rundt langs kanten og beskytter skabet.

# **ACKNOWLEDGEMENT**

We would like to thank our main supervisor Christian Tollestrup, who has challenged and guided us through a different, difficult yet interesting design process by motivating and pushing us forward when things god difficult. Also, a big thanks to our technical supervisor, Lars Rosgaard Jensen, who guided us through a processed filled with technical challenges when needed

A big thank you to Niels Holfod and Line Klivanger who have shared their real-life experiences and struggles, leading us to take upon a project like this.

Likewise, a big thank you to N1's Electrical fitters, Mads Erik Eriksen and Mathias Kodahl Jensen, in addition to electrician Jeppe Filt, who was kind enough to be available to give us valuable feedback and insight into their work of frame.

Finally, we would also like to say a special thank you to Per Sørensen from Trefor, who contributed with important and valuable knowledge, giving us the opportunity of during such a project. Furthermore, a thanks to Peter Klokkedal Sørensen from Triarca, for letting us into the world of cable cabinets. It has been a very interesting and educational experience, which has brough great value to the project.



Per Sørensen
Security of supply &
Director of Electricity
Supply at Trefor



**Peter Klokkedal Sørensen** Research & Development Manager at Triarca



**Jeppe Filt**Electrician

Illustration 2: Stakeholders

# **READING GUIDE**

The Nereus project is presented in four parts: A product report, a process report, technical drawings and an appendix with additional information and references material. It is recommended to read the product report before the process report is explored.

The process report consists of six phases that document the process of developing Nereus, excluding the Epilog. When entering a new phase, a chapter summary can be found. Throughout the report, Cable Distribution Cabinets will be referred to as either CDC or cable cabinet. In addition, three icons will appear when something must be noted. Reading the boxes will provide further elaboration.

All references are made with The Harvard Method, and a complete list of references and illustrations can be found at the end of the report.

#### Insight

This icon will appear when an investigation has given a relevant insight, moving the process forward.

#### Requirement

This icon will appear when results of an investigation can be translated into a requirement for the product proposal.

#### Reflection in // on action

This icon will appear when a relevant reflective note is tied to an investigation or observations regarding results of an investigation or the method.

**01** SCOPE

#### UNDERSTANDING THE PROBLEM

Chapter summary Flooding in Denmark Cable Distribution Cabinet Understanding Stakeholders & Experts The Initial Direction Triarca The Supply Chain Initial Design Brief

02 DEVELOPMENT

**EXPLORING THE SOLUTION SPACE** 

Chapter summary The Initial Design Approach Establishing an Overview The Electrical Fitter The City Architect Defining the Workspace Market Analysis Why can't we just? Design Brief 2.0

# 03 DEVELOPMENT

### A NEW TAKE ON CABINETS

Chapter summary A Combinatorial Design Approach Prototyping 1.0 The Concepts Mini Tests Feedback - An Experts' Opinion A Competition Design Brief 3.0

# 04 DETAILING PROVING THE CONCEPT

Chapter summary
Problem Slicing
Coating
Creating the Seal
How Do We Connect the Door and the Panel?
Defining the Interior Design
Addressing the Buoyancy
How Do We Close the Cabinet?
What About Condensation?
Nereus

# 05 DETAILING FINALISING THE CABINET

Chapter summary
Choosing The Materials
How To Look Like An Upgrade?
Prototyping 2.0
Production
How Is Nereus Assembled?
Product Specifications

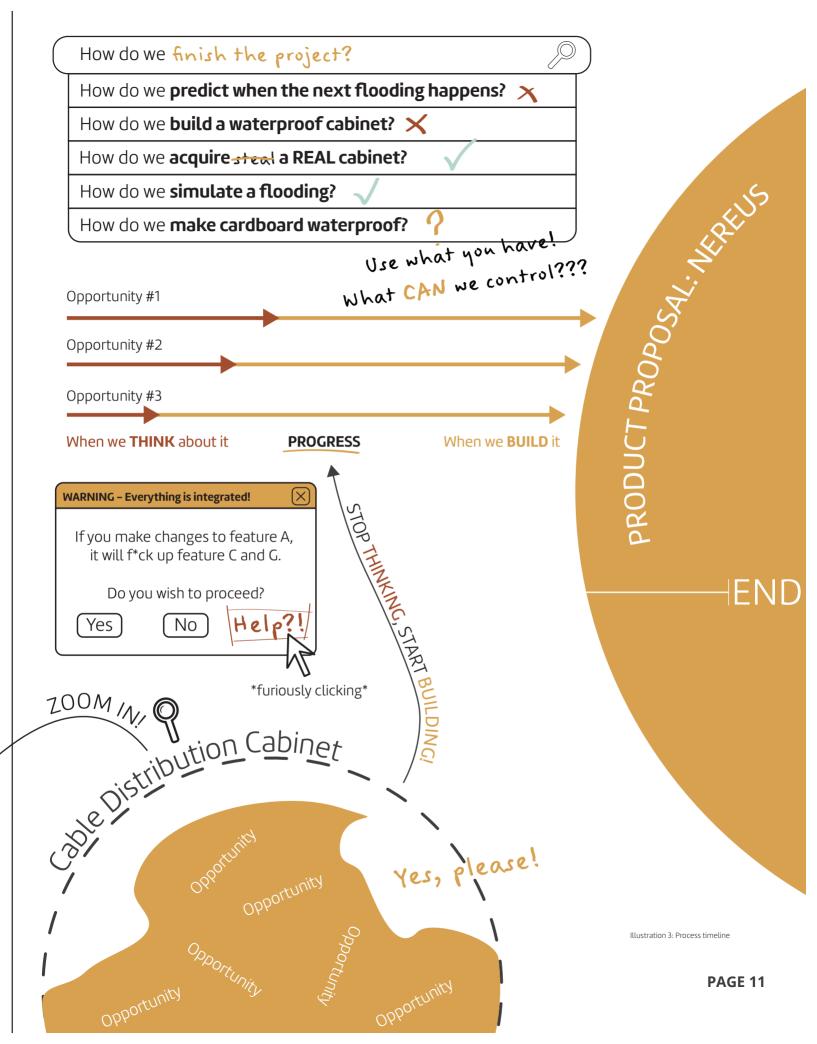
# 06 BUSINESS MARKET IMPLEMENTATION

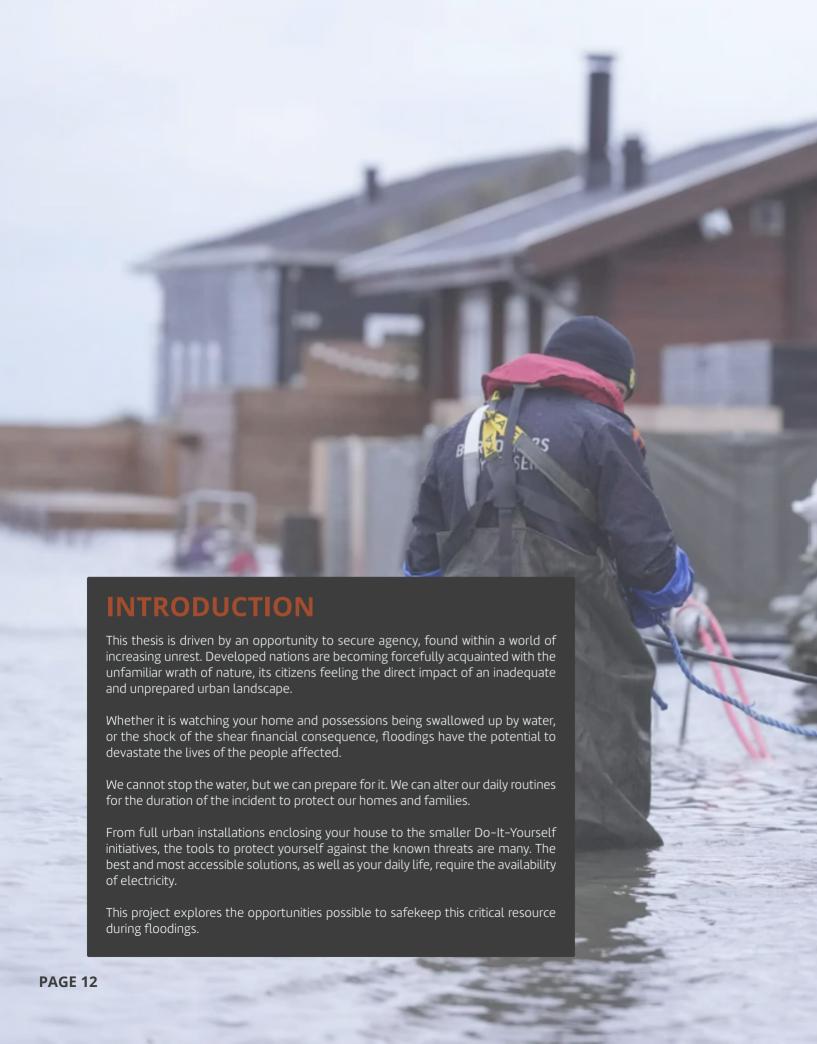
Chapter summary
The Value Chain
Estimating the Cost
Strategic Fit
Designing a Product Series
Implementation Plan

**O7 EPILOG**WRAPPING UP (AT LEAST FOR NOW)

Conclusion Reflection List of references List of illustrations Appendix

Problem Water getting into the CDC = no power = VERY BAD! "It's just a box, how hard can ix be and soro the world! Radical Innovation! a Can't you remove it completely?" Stakeholder #4 "No", e Distribution Cabinet Stakeholder #1 REDESIGN RETRUFIT QUICK FIX START Stakenoi. Objective: "IX RUINS Stakeholder#3 everything!" Make it WATERPROOF "Why don"t you But what does just...?" - Wrap it up? - Raise it? Nallis no ordinar - seal it? Form Follows Function Co-Evolution Here lies everything we usually do as design Design Thinking students **Entrepreneurial Mindset PAGE 10** save the World ... Radical Innovation...







# CHAPTER O 1 SCOPE UNDERSTANDING THE PROBLEM

# **SUMMARY**

In the scope phase the project frame will be outlined. An understanding and definition of flooding and its impact on society is established. The consequences are investigated through interviews so a project direction can be identified. A case study and analysis of the project direction is then done as preparation for interviews with the stakeholders in order to understand them and their needs. The following information is then processed culminating in three initial directions which are presented to additional stakeholders before choosing. The chapter ends with a dive into the supply chain of the user and how the product proposal can fit into it. The design brief summarizes information gathered throughout the chapter alongside a problem statement and requirements.

- 1.2 Flooding in Denmark
- 1.3 Cable Distribution Cabinets
- 1.4 Understanding Stakeholders& Experts
- 1.5 The Market
- 1.6 The Initial Direction
- 1.7 The Manufacturer
- 1.8 Initial Design Brief

#### Three types of flooding







Illustration 5: Three types of flooding

A flooding is defined as the submersion of normally dry land with an overflow of water (NSSL, n.d). Three different scenarios can lead to flooding, those being storm surges, fluvial flooding and pluvial flooding. A storm surge occurs when the sea-level rises due to a powerful onshore wind, often combined with high tides. A fluvial, or river flood, occurs when the water level in a river, lake or stream rises and overflows onto the neighboring land. A pluvial flood occurs when an extreme rainfall event creates a flood independent of an overflowing water body. (Zurich, 2023)

# 1.2

# FLOODING IN DENMARK

2023 was a record year in Denmark. The rainfall was the highest it's been recorded since records began 150 years ago. **As a consequence of the large amount of water, floodings became more severe and frequent** (Damberg, 2024). In the days 20th and 21st of October 2023 the worst storm surge in more than 100 years occurred in Denmark. It was the cause of extensive flooding (see info illustration 5 for explanation of flooding types) and is estimated to have caused 1.2 billion DKK of damage and affected 3300 households (Finanswatch, 2023). On illustration 6 a map of Denmark is seen with the areas officially hit by a storm surged highlighted (Naturskaderådet, 2023). However, large parts of Denmark were also affected by other types of flooding making the problem national and not limited to the zone defined by Naturskaderådet.

The proposal must be able to withstand future, more severe flooding incidents



Illustration 6: Stormflod, December 2023

On illustration 7–9 a comparison of different location in Denmark during floodings within the last six months can be seen. The consequences and damage done can be extensive. Cars are flooded and destroyed. Buildings and stores have to close due to surrounding water and less durable houses, shelters etc. are destroyed.





Illustration 7: Grandville, n.d. & Wiencken, 2023





Illustration 8: Trap Danmark, Knudsen & Larsen, 2021 & Ankerstjerne, 2023



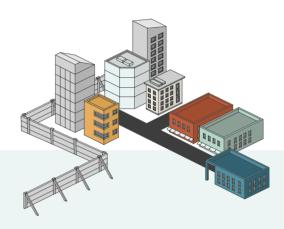


Illustration 9: Google, 2024 & Christensen, 2024

It's an issue that's only going to get worse in the future. DMI (Dansk Meteorologisk Institut) expects rainfall to become 10% more intense and 30-70% as frequent while incidents such as the October storm surge is becoming five times as frequent while surges in general will be 7-40 times as frequent. Thus, flooding is a problem that will become more relevant and its essential that society changes to accommodate for this new environmental challenge. (DMI, 2024)

# THE STAGES OF FLOODING



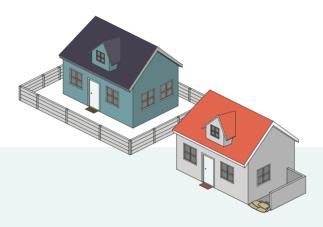


#### The Environmental Defense

Flooding is first of all dependent on rainfall and/or water bodies. Therefore, certain geographical locations will not be affected. However, due to climate changes and more intense rainfall these locations are dwindling (Walsh, 2023). Another aspect that affects this sphere is the increase in urbanization disrupting the natural ability of the environment to absorb large volumes of water (Stephenson, 1993) ultimately leading to flooding. In this sphere it's hard to implement solutions to prevent flooding due to scale.

#### **The Urban Defense**

The need for relocating water to prevent flooding has existed for many years. In many places today this task falls exclusively on the sewage infrastructure. An infrastructure that was built many years ago and has become obsolete due to increase in rain intensity. Some largescale solutions exist to prevent flooding on urban scale such as waterproof walls, dams, automated water barriers (app. 1). They are owned and managed by municipals and often take a lot of time to implement.





### **The Property Defense**

When the urban anti-flooding measures fail the problem becomes individual instead of societal. A point of emergency arrives for the consumer. Business— and homeowners have to invest in solutions on the commercial market which are often expensive (app. 2–5). Such solutions include water barriers, waterproof doors and windows or automated permanent solutions that can help protect the entire property.

#### The Private Defense

If you did not invest in the larger solutions, there are still ways to protect your home. Products directly targeted the consumer are widespread in other countries, such as the UK, ranging from blow-up physical barriers to products that block drains, preventing the backflow presented in the Urban Sphere. These are products that the consumer is tasked with installing on their own. While not as common to the Danish consumer, it does not negate the demand for sealing their homes against the incoming flood.

An interview was conducted with Stormflodssikring during the initial faming of the project to understand the market for anti-flooding products. After the flooding of October 2023 their business experienced an increase in inquiries from private consumers. Something that is also seen in their business model which has switched from 5% B2C to 60% over the last 15 years (app. 1)



# THE VICTIMS OF FLOODING

To get a better understanding of how flooding affects different individuals two semi structured interviews (delve, n.d.) were conducted. The first with Niels, a homeowner in Kolding who experienced flooding. The second Line, a shop owner in Faaborg.

"I had six submersible pumps going in the basement alongside multiple wet vacuum cleaners. But the water levels rose so much Ågade became completely flooded and the outdoor cable box started smoking and was shut off. In that moment as power went out, I lost since I didn't have anything to fight with. It ended up with 70 cm of water in the basement" – Niels Holfod, 2024



and went buying submersible pumps. I turned out i wasn't ready at all because the water came in through the foundation and walls. It entered where i didn't expect it."

Niels Holfod, 2024







Illustration 13



Illustration 12

Illustration 14

Niels was one of the many people whose property was damaged during the October 2023 floodings. His house is placed next to a creek and had never before experienced flooding and was of the conviction this wouldn't affect him (app. 4). This was a general behaviour observed by Stormflodssikring, if consumers hadn't experienced flooding, they wouldn't be willing to invest in waterproof solutions (app. 1). However, the intense rainfall and water from Kolding Fjord changed this for him. Illustration 12 show the water around his house as well as the creek.

During the interview two important insights were gained. The water did not enter through the airgaps around doors, windows and through drains. Although he managed to cover those himself (illustration 13). It entered through the walls and the floor, danamging the basement with his personal items (illustration 11 & 14). Secondly, he had the situation under control with water pumps until the electricity went out due to the power distribution cabinet short circuiting. Illustration 12 shows the water level in his basement after the power outage occurred.

Line is the owner of Faaborg Røgeri Cafe in Faaborg, Denmark. Her business is placed in the harbour district and is located close to sea-level. Due to a high likelihood of flooding the distribution company that owns the power grid in the area decided to shut off power for the docks making pumps impossible to use without a generator. In 2016 and 2017 she experienced flooding inside her cafe. Afterwards she tried buying big bags (illustration 15) to prevent the water from getting in, but it failed.

"In 2016/17 it started becoming more severe, so we had to think out of the box. What were we going to do in the heat of the moment? So, we got some big bags which we filled with 1 tonnes of sand in each and barricaded my cafe with these big bags. It required big machinery and was really expensive both before and after and it only worked partially"

Afterwards she tried alternative solutions but the only one that worked was a deployable wall (ill. 16). A solution only possible since a nearby warehouse allowed her to store them there for a small fee and the local fishermen helps her move them. In addition, she also acquired the generator and four pumps to stop water from ruining her cafe. The combination of these solutions helped her keep her cafe safe during the storm surges. (app. 5)



Illustration 15: Big bags

"We've tried to keep up with the development of products year by year. Each year I look into new products that would be smarter that what we currently have. Previously I've had a watertube but it took around 24 hours to set-up and 24 hours afterwards to remove. We had to find something more tangible that could be applied quicker and two years ago i found the boxwall." – Line Klivager, 2024

"We are lucky that we can rent some space in the storage buildings at the harbor so they can be stacked on top of each other, so they don't take up as much space. The local fishermen are also very helpful lending a truck we can use to move them" – Line Klivager, 2024



Illustration 16: Deployable walls (Boxwall)

#### Insight

After talking with both Niels and Line it was apparent that their loss of agency happened due to a power outage. Without the ability to pump out the water they become unable to manage the situation and the only option left is to do damage control. A deeper investigation into the Danish power grid must therefore be conducted to identify the critical area which is the cause behind Line and Niels' loss of agency.

# **CABLE DISTRIBUTION CABINETS**

An essential part of modern civilization is having access to electricity. We use it to power our lights, refrigerate our food, charge our phones and power a wide range of appliances, to just name a few things. When a severe flooding incident happens, this resource can be compromised. Most likely due to a failure in the power grid thus, removing agency from citizens as observed in the two cases of Niels and Line. When investigating the root of the problem, it is important to understand the infrastructure of the power supply from and where the problem occurs.

#### The Danish Power Grid

The electricity network in Denmark is divided into the transmission network, owned by the government (Energinet) and the distribution network which are owned by private companies. The transmission (Over100 kV facilities) network can be described as the highway that ensure Denmark can import and export electricity between the neighbor countries and between regions to consumer areas. The distribution network (Under 100 kV facilities), also described as country roads, ensures that electricity is connected between the transmission network and the consumers. (Ewii, n.d.)

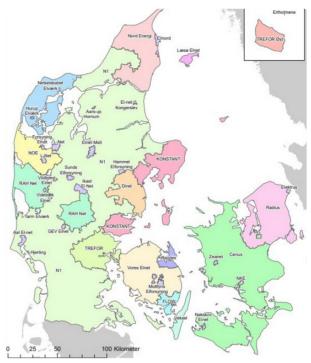


Illustration 17: Distribution Companies in Denmark

### **Protecting the CDCs**

When looking at the power grid and comparing to the insights gathered from Niels and Line the distribution network can be identified as being the vulnerable part of the power grid. The cable distribution cabinets (hereafter also referred to as CDC) are of particular risk as explained by Niels. In addition, during desktop research it was discovered that Trefor, a distribution company in Kolding, Denmark, had to shut down 400 cabinets pre-emptively to prevent damage ultimately leaving 1550 residencies without power during the storm surge in October 2023. Furthermore, Trefor had to check the cabinets whereof 225 had to be cleaned and 50 replaced due to water damage (Ritzau, 2023). It was decided to dive into the problem of protecting the CDCs and distribution network during flooding incidents to secure the supply of electricity for the consumers.

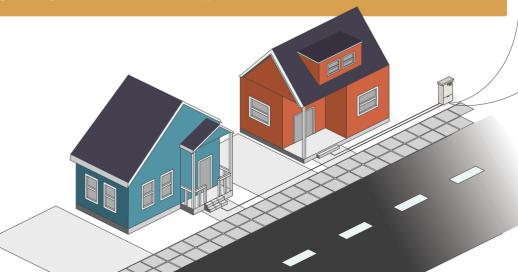
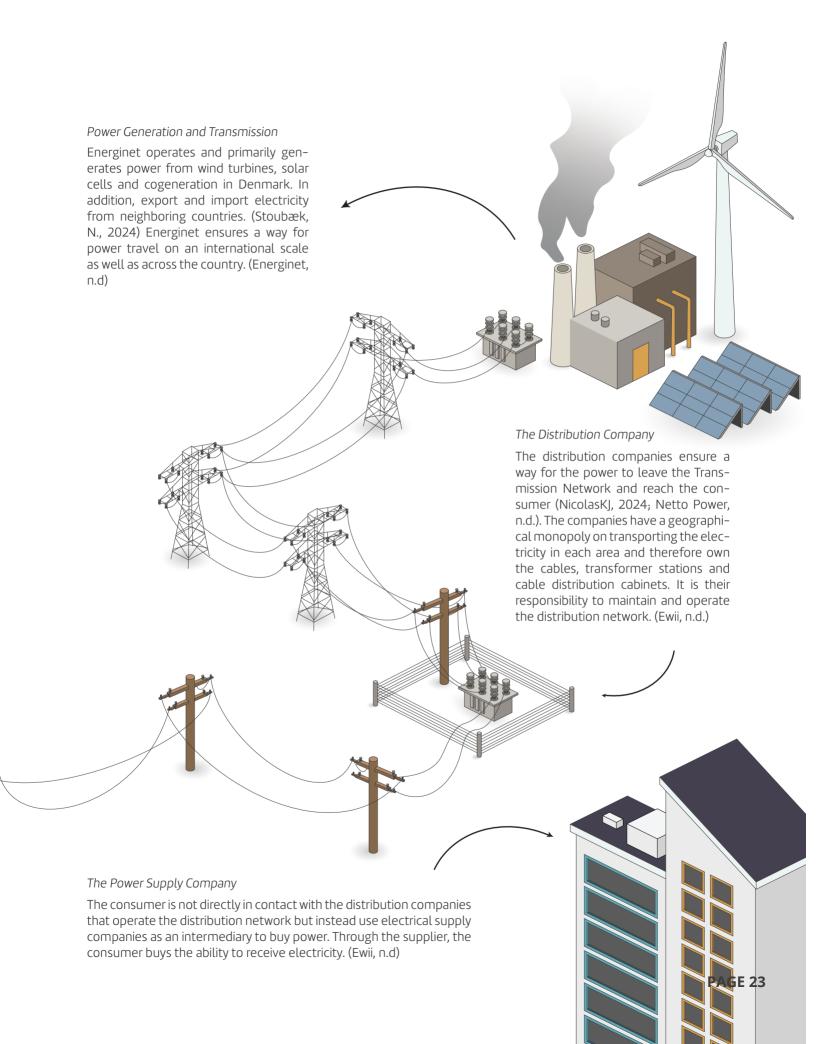


Illustration 17 The Danish Power Grid



# CASE STUDY OF CDCS IN THE URBAN SPACE

With an understanding of the power grid, a case study of cable distribution cabinets in the urban environment was conducted in Aalborg. The goal was to gain a visual understanding of cable cabinets, their placement and how they affected urban space and vice versa. The study was divided into two. Firstly, CDCs in Aalborg Downtown area was investigated before moving on to a suburban area in Aalborg.

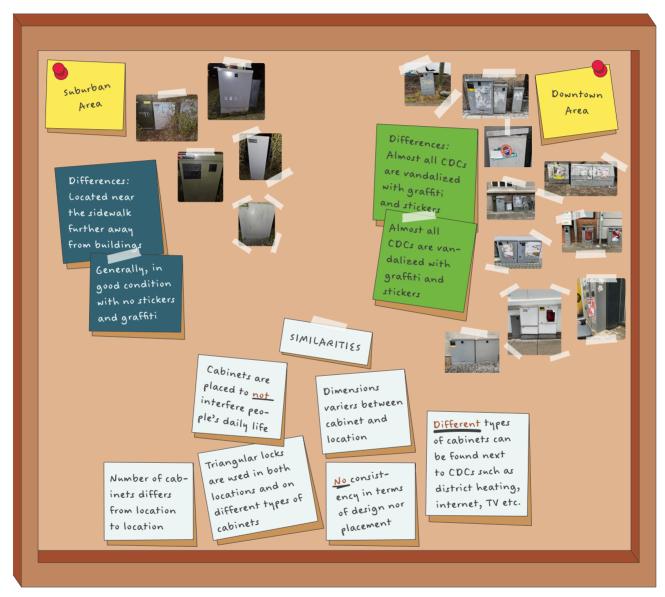


Illustration 18

#### **Evaluation**

The cabinets are generally placed with the same intention regardless of whether it is in the suburbs or the Downtown area. The most notable difference is the condition of the cabinets. In the Downtown area they were vandalized, which probably is due to the demographic differences and traffic around them. The placement of the CDCs also varied by a small amount, even though it was mostly due to the houses in the suburban area be-

ing withdrawn into private property. When looking at the similarities, two things especially stand out. First is the difference in size, number, design and use of cabinets from location to location. It seems as though, the same types of cables cabinets whether placed in the suburban or the downtown area. The other is the use of triangular locks (see illustration 18) across all cabinet types and are particularly interesting for a product proposal.

# THE CDC ZOOM

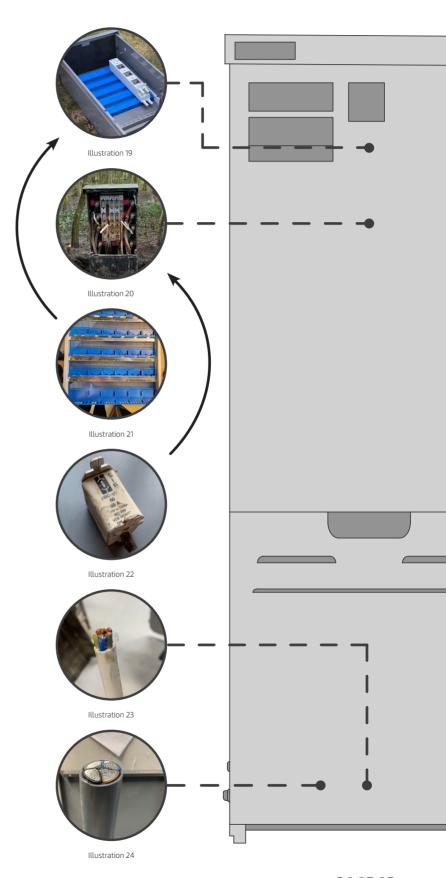
With a basic understanding of how the CDCs are connected to the power grid and their place in the urban environment, a deep dive into the actual cabinet from a functional view was conducted. The goal is to identify the different components that make up a distribution cabinet and how these components interact and fit into a functional use.

The CDC is connected to the distribution network through supply cables. These cables are Ø50 mm wide, holding four sub-cables inside (Neutral, L1, L2 and L3) (Bjerre, 2017; Mcfadyen, 2012) which is shown on illustration 24. Inside the CDC four busbars are placed (illustration 21). Produced in a conductive material such as aluminum or brass, these busbars are placed horizontally to distribute power to each cable. Each of the four sub-cables are connected to their own busbar and ensures a power connection to the next CDC in the power grid (illustration 20). (DESG, 2022; Figabara, 2021) A fuse switch (illustration. 19 is placed vertically to the busbars, attaching to each of the four busbars, ensuring a power connection (DESG, 2022; Figabara, 2021). Through the fuse switch a power cable is connected, gaining access to each of the four busbars. The fuse switch is a safety measurement. (Elgrossisten, n.d). If the circuit should overload, the fuse (illustration. 22) will disconnect the circuit preserving the connection and prevent damage. (Elgrossisten, n.d). The power cables (see illustration 23) running into the houses are smaller than the supply cable and can be anywhere from Ø4 mm to Ø25 mm (Elgrossisten, n.d).

#### **Evaluation**

When evaluating on the research of the Danish Power Grid and identifying the cable distribution cabinets as the weak link in the infrastructure, a decision to contact the owners of the CDCs was agreed upon. Trefor was contacted due to the company voicing their concerns and problems publicly. In addition, at this stage of the process, the understanding of how flooding was impacting a cable cabinet and the distribution company internally.

The product proposal must be applicable in all contexts



# UNDERSTANDING STAKEHOLDERS

The distribution companies become an interesting stakeholder, as the solution to prevent the loss of agency become targeted towards them, instead of the likes of Niels and Line. Without being able to provide security of supply, the distribution companies fail to uphold their task in the power grid. Trefor estimates that the financial consequence of the October 2023 incident was 3-4 million (Ritzau, 2023). This covers the likes of replacing cable cabinets and cleaning cabinets that can avoid replacement. The biggest expense for Trefor is possibly the salary of the Electrical Fitters, the employees in the field, interacting with the CDC's, working overtime to establish supply of power to the consumer. A meeting was conducted with Trefor's Head of Power Supply, Per Sørensen (app. 6). Through the interview multiple insights of the incident were gathered. In addition, images provided to showcase the consequences of flooding in relation to cable distribution cabinets. On the illustrations 25–28 the damage done by the water can be seen.

#### The Electrical Fitter

Through the interview a new stake-holder was discovered. Electrical Fitters are employed by the distribution companies who will interact with a possible solution. Establishing contact with the segment (c.f. 'Development - Exploring the Solution Space' - 'The Electrical Fitter') will lead to insights regarding the current workflow and features of the CDCs alongside valuable feedback on concepts.



llustration 25

The styrofoam protective layer in the bottom of the CDC, preventing snails and other small animals or insects from crawling into the cabinet was destroyed by the water.



Illustration 26

The water caused the wires to short circuit. The cable distribution cabinet broke into flames and was destroyed.



llustration 27

Quick-fix solutions are implemented to protect the cabinets so people can maintain power, until the Electrical Fitters can safely access the CDC underneath.



Illustration 2

Moving debris in the water has destroyed the corner of the CDC, compromising the interior

The surface must not be conductive

The product proposal must be resistant to salt

Illustration 29 showcase all the cabinets affected by the flooding back in fall 2023. The green dots on the map indicate which cabinets had to be inspected after the incident. The yellow dots show which CDC that had to be cleaned after the water level was back to normal, and the orange dots which was either destroyed or too damaged and had to be replaced.







Illustration 29

"We had 300-400 cable distribution cabinets affected by the flooding [...] multiple had to be replaced due to the water levels."

Network Companies are not the only profession to struggle in this situation.

"When the cabinet is cleaned or the cabinet is placed in a salty area, it is in risk of leakage current. It means a layer of salt, if not cleaned properly can conduct a current, which is dangerous."

Leftover salt can cause leakage current and potentially short-circuiting or harm to the electrica fitters or citizens.

"When the water is gone, we need to re-activate the cabinets. However, this can't be done before we've cleaned with a high-pressure cleaner and dried them, which in some cases aren't even enough."

The standard of the networking companies.

"Cutting the power supply for our customers is never good. It has a societal value, and its expensive for Us as a company since our products aren't capable of withstanding the water."

The lack of products capable of withstanding flooding costs the companies economically and affects the societal values.

"We chose to cut the power supply pre-emptively, because if we don't, the water short-circuits the cabinet."

If the power is active during a flooding, there is a high risk of short-circuiting during flooding

"There are other stakeholders which uses similar cabinets such as streetlight, traffic lights, district heating, TV, internet etc."

Flooding is an extensive problem for the networking companies

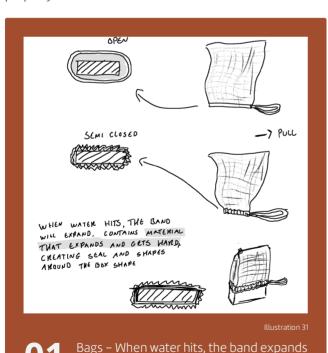
During the dialogue with Trefor, the team were able to specify the underlying problem, the distribution companies face today. The lack of cable cabinets capable of withstanding flooding forces the distribution companies to shut off the power. If not, there is a risk of leakage current and short circuiting which can be dangerous. The distribution companies therefore must do damage a control to minimize the number of cabinets affected to reduce follow-up repair and maintenance cost. This information led the foundation of the initial design directions which will be presented in the following section.

# **INITIAL DIRECTIONS**

To start off the ideation an open brainstorm session was conducted through sketching to identify initial ideas and directions based on the insights gathered from research and interviews. The goal of the collective brainstorm was to explore different techniques or methods for protecting the cable distribution cabinet from being flooded. The output of the session (illustration 31-37) was clustered afterwards and led to three different categories. After clustering into three directions these were evaluated to see if there were any advantages or disadvantages based on the team's current knowledge. By doing this the team realised that numerous challenges with the quick-fix solution ex-

#### **Quick Fix Protection**

Description: This direction covers protection methods by proposing an 'add-on/take off' solution to the existing CDC's. The characteristics of the ideas are primarily temporary solutions, installed by the power distribution companies before flooding occurs. In addition, the solutions are inspired by current flooding preventions methods for property or business owners.



and create a seal shaped like the given

THE PUSH DOWN WALL

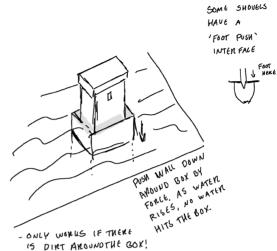


Illustration 32

IDEA CDC.

Barriers are installed before a flooding incident to prevent the water from entering the



Illustration 33

Air bag - A bag is placed over the CDC and air is pumped to even the pressure from the ris-**IDEA** ing water.

# Why not 'quick-fix'-solutions?

- X Flooding is unpredictable.

IDEA CDC.

#### **A Retrofit Solution**

Description: This direction covers protection methods by proposing an additional permeant 'add-on' solution the existing CDC's. Mostly inspired by current urban solutions, the characteristics of the ideas are the radical change needed to protect the CDC.

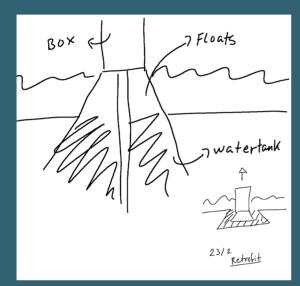


Illustration 34

Urban solution – When the water level rises, the water push walls upwards and protect the CDC.

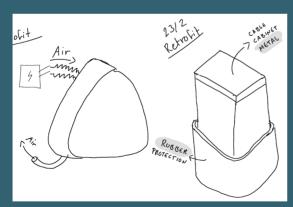


Illustration 35

Rubber seal – To seal the bottom of the CDC, a big rubber ban is placed to prevent water penetrate the cabinet.

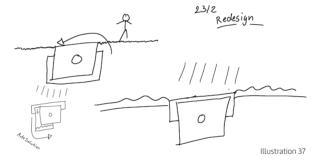
#### **Redesign - A New CDC**

Description: This direction covers the exploration protecting the CDC by designing a new waterproof cabinet. The characteristics of the ideas are radically different than the existing by moving the cabinets underground.



Illustration 36

Underground – If the cabinet is moved underground permanently, flooding becomes a non-issue.



02 IDEA

Titling – When flooding warning is given, the cabinet can be rotated underground.



# Why not Retrofit or Redesign?

During sketching an observation of the difficulty of redesign ideation is made. Due to missing information regarding how a cable distribution cabinet is assembled and designed, it was difficult to ideate incremental changes. The proposed solutions became radically different in terms of interactions but remained the same aesthetically. At the time, a new perspective of the cable cabinet was needed to further the exploration of a redesign. Product direction remains open between a retrofit design and redesign.

# **TRIARCA**

To aid the process of choosing between the retrofit and the redesign direction, Triarca was approached due to the company being a leading manufacturer of CDCs in Denmark, but also to provide valuable expert knowledge on cabinets. A meeting was conducted with Peter Klokkeldal Sørensen, Triarca's Research and Development Manager. The aim of the interview was to understand which aspects that should be considered when designing a cabinet, to get feedback and comments on the two initial directions. The following section states the key insights the interview. (app.

New stakeholder The City Architect

The product proposal must be non-intrusive in the urban space

"[...] Our transmission network (power grid) is unique compared to the rest of the world. There are only four manufactures in Denmark, us included. Other countries won't design to ours, it's too small. "

The product proposal must fit into the existing infrastructure of the power grid

"Installing an extension solution requires permission"

The proposal must function without needing permission in the build-up phase off an incident

"...The IP class is a parameter of competition..."

The product must be resistant to all types of water

"We are already looking into a way to secure the cabinet without altering its dimensions."

The solution must fit the standards dimensions

#### Who can refuse a CDCs?

The City Architect (will also be mentioned as CA) was a new stakeholder identified through the interview with Triarca. It was discovered that ten of Denmark's municipals have a CA, and their job varies from consultancy to city development and political advisors for the building industry (Arkitektforeningen, 2024). As a part of their job, they must ensure a coherent visual urban architecture and a part of that is placement and expression of cable cabinets. With the power to refuse the placement of a CDC if it disturbs the vision of the urban environment, it is essential to understand their needs especially regarding the aesthetics of the product. The next step for the proposal's aesthetic development is to contact the CA for insights ('Exploring the Solution Space' – 'The City Architects').

Illustration 38: Peter K. Sørensen, Triarca

With additionally information gained, a revaluation of the initial product direction could be decided. When discussing retrofit it was important to differentiate between an 'Internal retrofit solution' (a solution that is added inside the CDC) and an 'External retrofit solution' (a solution added outside the CDC):

# Why not choose the retrofit direction? (Internal solutions)

The solution space requires electromechanical knowledge the team does not possess. In addition, it is a temporary solution that becomes irrelevant when cable cabinet companies develop a solution.

# Why not choose the retrofit direction? (External solutions)

Like the internal solutions, it is a temporary solution. Furthermore, the context of the CDC's varies in terms of terrain, the space around the cabinet is depended on the area it its placed, and the number of cabinets placed together.

#### Choosing a redesign

It is a permanent solution, that contrasting to retrofits, won't become irrelevant in the future.



What are Danish standards and are they important? – During the interview with Peter K. Sørensen, R&D (Research and Development) Manager at Triarca, Danish Standards was introduced to the project. Danish Standards ensure a common language is spoken between companies no matter the origin country. Common guidelines ensure safety, and a common standard is met when new products are introduces to the market. To ensure the solution can be implemented, Danish Standards for 'Low-voltage switchgear and controlgear assemblies – Part 1: General rules' (DS/EN IEC 61439–1:2021) (App. 8) and 'Low-voltage switchgear and controlgear assemblies – Part 5: Assemblies for power distribution in public networks' (DS/EN ICE 61439–5:2023) (App. 8) are covered. Although these are requirements for the solution, these will be seen as the framework for the design. The guidelines are added to the product specifications list and not seen as requirements.

#### (DS/EN IEC 61439-1:2021)

- The solution must be labelled
  - Manufactures name or trademark
  - Type designation or identification number or any other means of identification
  - Means of identifying data of manufacture
  - Rated current of the assembly
  - Rated voltage of the assembly
  - Rated frequency of the assembly
  - IEC 61439-X (X shall be defined)
- The ambient air temperature must not exceed +40 degrees (average over a period of 24h does not exceed 35 degrees. And under -25 degrees.

#### DS/EN ICE 61439-5:2023)

- Must be able to operate in the temperature interval
   -25 to 40 degrees Celsius
- Must be able to operate in 100% humidity in -temperature interval -25 to 27 degrees Celsius
- Must have an IK code of 10
- Must have an IP code of 34D+
- Must have a lock that prevents the public from accessing the interior
- Must be UV resistant in temperate climates
- The cables must be easily connected through the front
- Cables must enter the cabinet from below



#### THE SUPPLY CHAIN

When redesigning the CDC, it is important to take distribution companies business model into consideration. The Distribution companies' role is as mentioned earlier (c.f. 'Cable Distribution Cabinets') to maintain a part of the power grid. When the consumer pays their power supplier, they pay an additional fee to the distribution company to use their cables to transport the power. However, the consumer is not directly in contact with the distribution company (Energistyrelsen, 2023). This fee is called a 'Tariff' and is part of the distribution company's source of income. As previously mentioned, each company has an assigned geographical area to maintain and operate (c.f. 'Cable Distribution Cabinets'). This means the num-

ber of potential customers is somewhat fixed. Their only way to increase revenue is therefore to reduce expenses or increase revenue. Their revenue however is fixed since the tariff are regulated by a third party. Price is therefore the main point of competition for manufacturers of cable distribution cabinets. (NicolasKJ, 2024)

Although exploration of initial concepts for the redesign should be explored, it will be in the distribution companies' interest to not sway from their current supply chain (Illustration 39).

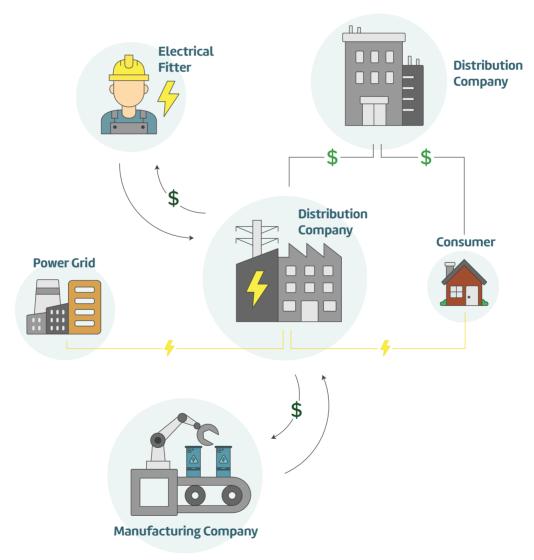


Illustration 39

#### **INITIAL DESIGN BRIEF**

#### Introduction

This project explores consumers agency during a flood. A cable cabinet to accommodate the changing climate and minimize the risk of power outage. The focus is to tackle flooding of cable distribution cabinets by designing the cabinet of the future.

#### **Target group**

Distribution companies.



#### **Problem Statement**

How to design a waterproof cable distribution cabinet that ensures security of supply, during flooding, while fitting into the established infrastructure of the distribution companies and Danish power grid.

#### Goal

To provide consumers like Niels and Line with agency during flooding incidents by maintaining the electrical supply to their home, so they can take measures into their own hands during incidents.

- The proposal must be able to withstand future, more severe flooding incidents p. 14
- The surface must not be conductive p. 24
- The product proposal must not corrode
  - The product proposal must be resistant to salt p. 25
  - The product proposal must be resistant to all types of water p. 28
- The product proposal must fit into the existing infrastructure of the power grid p. 28
- The solution must fit the standards dimensions p. 28



- The product proposal must be non-intrusive in the urban space p. 28
- The product proposal must be applicable in all contexts p. 22
- The proposal must function without needing permission in the build-up phase off an incident p. 28



- The solution must be labelled
  - Manufactures name or trademark
  - Type designation or identification number or any other means of identification
  - Means of identifying data of manufacture
  - Rated current of the assembly
  - Rated voltage of the assembly
  - Rated frequency of the assembly
  - IEC 61439-X (X shall be defined)
- The ambient air temperature must not exceed +40 degrees (average over a period of 24h does not exceed 35 degrees. And under -25 degrees.



- Must be able to operate in the temperature interval
   -25 to 40 degrees Celsius
- Must be able to operate in 100% humidity in -temperature interval -25 to 27 degrees Celsius
- Must have an IK code of 10
- Must have an IP code of 34D+
- Must have a lock that prevents the public from accessing the interior
- Must be UV resistant in temperate climates
- The cables must be easily connected through the front
- Cables must enter the cabinet from below

#### **CHAPTER**

# **O2 DEVELOPMENT** EXPLORING THE SOLUTION SPACE

#### **SUMMARY**

The following chapter starts the converging process (Dubberly, n.d.) by initiating the development phase of the project. As the initial sketching rounds progress, the team is ultimately forced to take a step back diverging in the process (Dubberly, n.d.) to establish an overview of the stakeholders and which one has influence on what element of the cable distribution cabinet. To gain a better understanding of the solution-space (Dorst & Cross, 2011), interviews with two distribution companies' employees are conducted where their workflow is observed through shadowing (Bagger & Sperschneider, 2003). Furthermore, the team acquires two different cabinets for deconstruction. While a new stakeholder is introduced to give insights on the aesthetic aspect of the CDC. The chapter concludes with an analysis of existing CDCs on the market and why certain existing solutions fail and can't be implemented.

- 2.2 The Initial Design Approach
- 2.3 Establishing An Overview
- 2.4 The Electrical Fitter
- 2.5 The City Architect
- 2 6 Deconstruction of a CDC
- 2.7 Defining the Workspace
- 2.8 Market Analysis
- 2.9 'Why can't we just'?
- 2.10 Design Brief 2.0

#### THE INITIAL DESIGN APPROACH

With a well-defined problem another ideation round is conducted to try and converge towards initial concept directions that can be tested and evaluated in context. Before initiating the ideation, a case study of different sealing methods is conducted to gain inspiration from other products and contexts.

#### Case study of sealing methods

To understand different sealing methods that can be used in relation to a product proposal different reference products are investigated.



#### **Neck dams**

A neck dam (illustration 40) is a piece of equipment used on full-zip suits in certain conditions, such as diving, with the purpose of creating a seal between the attachable helmet and the rest of the suit. The neck dam is split in four components to create a seal around the diver's neck: (Kirby Morgan Dive Systems,nu.d)

- Split ring
- O-ring
- Stepped neck dam ring
- Screws spaced evenly out



#### **Space suit zippers**

A special kind of zipper is commonly utilized in equipment for traversing space. On a spacesuit, a piece of rubber is layered in between two zippers. When the suit is pressurized. The rubber expands within the sandwich (illustration 41) of zippers and rubber, creating an airtight seal. (Lewis, 2015)



Illustration 41



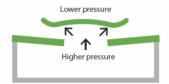
#### Illustration 42

#### **O-rings**

O-Rings is a sealing component that is placed in-between two parts in a groove. They are often designed with a O-shape but can be found in a variety of shapes. When the two parts are compressed together the O-ring will deform due to its elastic material and fill out the groove between the parts creating either an air-tight or liquid-tight sealing depending on design. (Apple Rubber, 2021)



Illustration 43



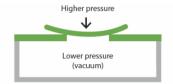


Illustration 44

#### Vacuum containers

The vacuum containers on illustration 43 is a product that helps make food last longer by removing the air inside. When applying pressure on the button the lid is pressed down (illustration 44) forcing air out of the container. When the button is let go an airtight seal is created by the gasket. Due to pressure differences a vacuum is created on the inside. When the button is pressed again the gasket and lid moves downwards letting air back into the container neutralizing the pressure. (Davis, 2021)

#### **Rubber gasket**

Rubber gaskets (illustration 46) are used to seal the space between two surfaces or joints. (Santopseal, 2022) Unlike O-rings they do not require a groove to be placed into. The gasket can be in a variety of different shapes such as triangles, squares, circles or different polygons depending on needs. They can also be designed in both rigid and flexible material after use scenario. Apple Rubber, 2021,)



Illustration 45



Illustration 46

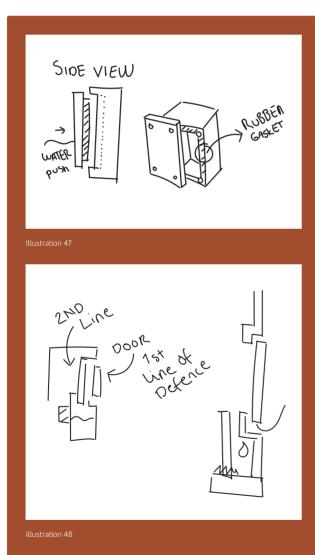
#### **Cable glands**

Cable glands (illustration 46) are a product used to secure cable entry from one area to another. This could be outdoor cables into electric enclosures. When tightening the cable gland, an internal rubber gasket creates a seal around the cables, protecting the electrical components from liquids, dust and moisture. (RS components LTD, n.d.)

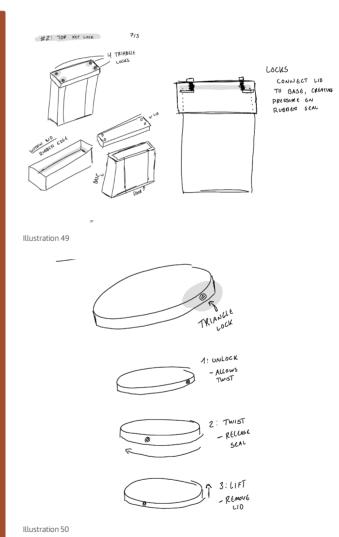
#### **OPEN IDEATION**

With inspiration gathered from different sealing techniques a new ideation phase is initiated and an open brainstorming session was used to generate concepts. The ideas are based on the problem statement and focus on a redesign of the cable distribution cabinet. On illustration 47–55 some of the concepts can be seen and the remaining concepts generated can be found in appendix 10. After the ideation round the concepts were clustered into four categories: Cabel entry, Door, Lid and Radical designs. During the development of the concepts and while clustering them it became apparent that there were certain issues with the concept generated.

# 01 DOORS CATEGORY



# 02 LIDS CATEGORY



# 03 RADICAL DESIGNS CATEGORY



713

#3: ??? Purber slides

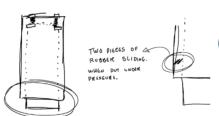


Illustration 52

Illustration 51



Illustration 53

## **04** CABLE ENTRY CATEGORY

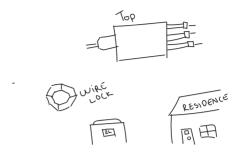


Illustration 54

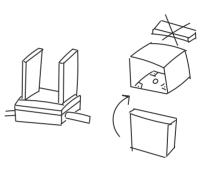


Illustration 55

The first insight gathered was related to the detailing of the ideas. It became too much of a 1:1 implementation of different sealing strategies into the existing cabinet. This was particularly visible on illustration 54-55 in relation to cable glands. The remaining design of the cabinet were almost identical to existing CDC designs leaving much of the solution-space unexplored. Secondly, concepts in the door and lid categories became too focused on fixing exposed openings of the current CDC design, thus limiting the solution-space instead of exploring the feasibility of more radical ideas such as those seen on illustration 50-53. Lastly, since the requirements found in Chapter 1 '(Understanding the Problem') were very functional and technical orientated it became difficult to develop ideas that aesthetically differed from the current CDC design. In addition, when trying to solve the entire design of the CDC in one go, the ideas quickly got deemed a failure or 'not good enough' to the concepts not being detailed enough for the requirements.

#### PROBLEM SLICING

By evaluating the previous process through reflection-on-action (Malinin, 2018) the team decided upon a new approach. To unfold the ideation process and allow for a better exploration of the solution-space (Dorst & Cross, 2001) a new approach to concept development were attempted. To make the process easier the problem was sliced into nine sub-problems (Dubberly, n.d.). By doing so, the team had less requirements to consider at once, by only focusing at one problem at a time. Each sub-problem was brainstormed upon individually and the results can be seen on illustration 57.

#### The perfect solution

After coming up with different ideas for the nine sub-problems an attempt to combine them were done. This process was inspired by Ulrich and Eppinger's (2016) product specification rating method. Each idea was evaluated based on the requirements. The goal was to identify the best sub-solutions for each problem to combine into one overall concept for the product proposal. Each requirement was weighted equally, and the solution were rated from 1-5 with five being the best. The results led to the following product proposal:

- Using screws
- Rubber gasket
- Invisible interaction
- ( Cable glands
- Door/Panel front
- Cable Cabinet

Illustration 56

Combining the different solutions into the "perfect cabinet" however, did not succeed. The attempt to slice into sub-problems, to make sub-solutions (Dubberly, n.d.) and then to a concept was a good approach but ultimately failed. This was due to three things happening simultaneously. 1) The initial sub-solutions are simplified to a principal level. Combining them, however, didn't show how they would interact with each other which led to stagnation in the design process. 2) The perfect solution becomes a generic cabinet design since the requirements are primarily technical and functional and little is known regarding aesthetic and interaction. 3) Not all principes are compatible with each other and not all requirements can be used on every idea. This makes it hard to compare solutions properly. A consequence which also ultimately led to the base construction and the ground sealing being excluded from the process.

#### 1. Door/cover (Open mechanism)















#### 2. Door/cover (Sealing method)











#### 3. Roof construction

















#### 4. Base construction















#### 5. Interaction











#### 6. Locking mechanism





#### 8. Cable entry











#### 8. Cable entry











#### 9. Shape



Illustration 57

The problem slicing method helped creating ideas and principles for solving different problems however, stagnation happened since it became too complicated combining the sub-solution into one overall concept. The next step is therefore to diverge the process (Dubberly, n.d.) and gather more information especially in relation to aesthetics and interaction before proceeding with concept development.

#### **ESTABLISHING AN OVERVIEW**

During Chapter 1 'Understanding the problem' four different main stakeholders were identified whereof two were interviewed. The goal with these is to obtain information, insights and feedback throughout the project. During the 'Initial Design Approach' stagnation occurred due to the lack of knowledge however, some known unknowns were identified being aspects of aesthetic and interaction. To maintain an overview of the different stakeholders and what information originates from whom the following board (seen on illustration 58) has been made. It is constituted of four aspects from each of the four stakeholders: Key insight, Relation to cabinet, Known unknowns and Requirement. The latter is an accumulation of each stakeholder's requirements and needs.

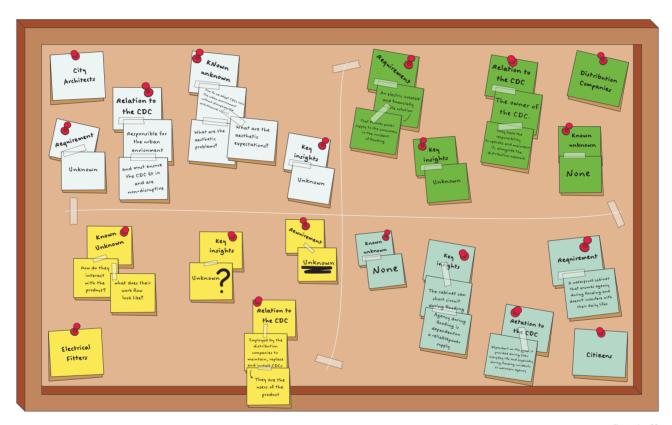
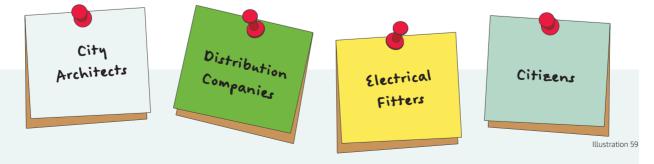


Illustration 58

During the remainder of the report an icon will be present when working with one or more of the four main stakeholders. Illustration 50 showcases the different stakeholder icons.



#### THE ELECTRICAL FITTER



To identify the electrical fitters known unknowns (c.f. 'Establishing an overview') in relation to interaction two different distribution companies are contacted to establish a meeting. Both meetings are a combination of a semi-structured interview (Delve, n.d.) and shadowing (Bagger & Sperschneider, 2003) where their workflow in replacing a CDC is observed. The company with geographical monopoly ('understanding the problem' – Cable Distribution Cabinets') in Aalborg is N1 and they were therefore contacted. This interview was conducted on site where a cable distribution cabinet was being replaced. It had been heavily damaged by a snowplough (see 'step 2' on illustration 60). Besides the interview N1 also provided technical drawings for some of their cabinets and an extension module. Both the new and old cabinet were Triarca Trilite cabinets. Replacing a cabinet is a one-person job but for safety reasons two people must be present. During the replacement of the cabinet the team documented each step. These are presented in the storyboard on illustration 60. In addition, new insights were gathered (app. 11) leading to a new set of requirements which are shown on their respective position in the storyboard.



The barrier is removed so the electrician can access the damaged cabinet.



The plastic is removed.



The new cabinet and fuse boxes are unpacked.



The cabinet is unlocked with a triangle key, and the cover is removed. The is installed.



Illustration 60

While one electrician unpacks the cabinet, the other electrician collects the tools.



An electrician moves to another cabinet and cuts the power.





The damaged cabinet is opened.



Before the electrician can take out the fuses, he measures the voltage to ensure the power is off.



With a 'Wrench' and drill the electricians are removing the fuse boxes.

The busbars must be fixed into place



the cabinet, the strips that hold the wires in place are cut.



The electrician removes the damaged cabinet by digging.



Due to the new cabinet being taller than the damaged cabinet, the electrician digs the hole deeper to not replace the cables.



The electrician attaches the wires to the cabinet with strips.

It must be possible to lock the cables in place



An electrician replaces the cabinet labels by transferring the letters to the new cabinet.

The ID must be transferable from the old design



The electrician slides the covers in place and locks the cabinet with the triangled key.

The front door must not intersect with the terrain

A new known unknown has been identified through shadowing. The workspace for which the fitter can work can be limited due to terrain, buildings, roads etc. This area needs to be investigated further to understand interaction limitations. Another key insight gathered during the interview was, that the importance of the coating. Cabinets today are coated to prevent leakage current from happening since the metal is conductive. However, if the coating starts to crackle or someone interferes with the surface by for example painting it or vandalizing

it with graffiti the safety can no longer be guaranteed by the distribution companies. The electrical fitters therefore always do a visual check for this alongside rust that has the same effect when working with a cabinet (APP 11). In the section 'Understanding the problem' – 'Cable distribution Cabinets' a case study was done to observe cabinet in the urban space. When looking at the safety of these a lot of them are compromised due to stickers and graffiti posing a potential safety hazard.

#### Replacing a cabinet with TREFOR

To gain additional insights into the process of replacing a cable cabinet, a visit with Trefor's electrical fitters in Vamdrup was conducted (app. 12). This was to verify that the process of changing a cabinet is the same as N1. In addition, to see observe the problem of a flooded cabinet first hand. Like the N1 visit, an on-site interview in addition to shadowing was conducted. An ABB Combi-Line (see illustration 61) cable distribution cabinet had been partially submerged in water for 14 days back in October 2023 and needed to be replaced. The new cabinet is a Triarca Trilite cabinet with a 1-meter extension to accommodate for future floodings.



Cables are cut.



Fuses are installed.



New cables are extended and tiltet into the cabinet.



Shrink wrap is placed to gather the cables.



Cables are attached to the fuses

From observations and the conversation with the electrical fitters during the outing, a few additionally insights were added to the data collection. When opening the cabinet, the most noticeable was the way, that the inner components was placed (shown on step 1) differently from the Triarca Trilite cabinet. This meant, unlike the N1 visit, the fused had to be installed in a different way. As mentioned, on the replacement, a 1-meter extension was added to the cable cabinet causing a cable extension to be had before installing the fused. Furthermore, an extension was only possible due to the context and the location of the cabinet. Had the replacement happened in an urban city area, an extension would not be possible due to covering of residents' windows. Another key insight was the importance of the cables being dry when mounted on the fuses or during the extension of cables. The electrical fitters used alcohol to wipe off any dirt and to make sure the cables are dry.

It must be possible to remove the entire front face

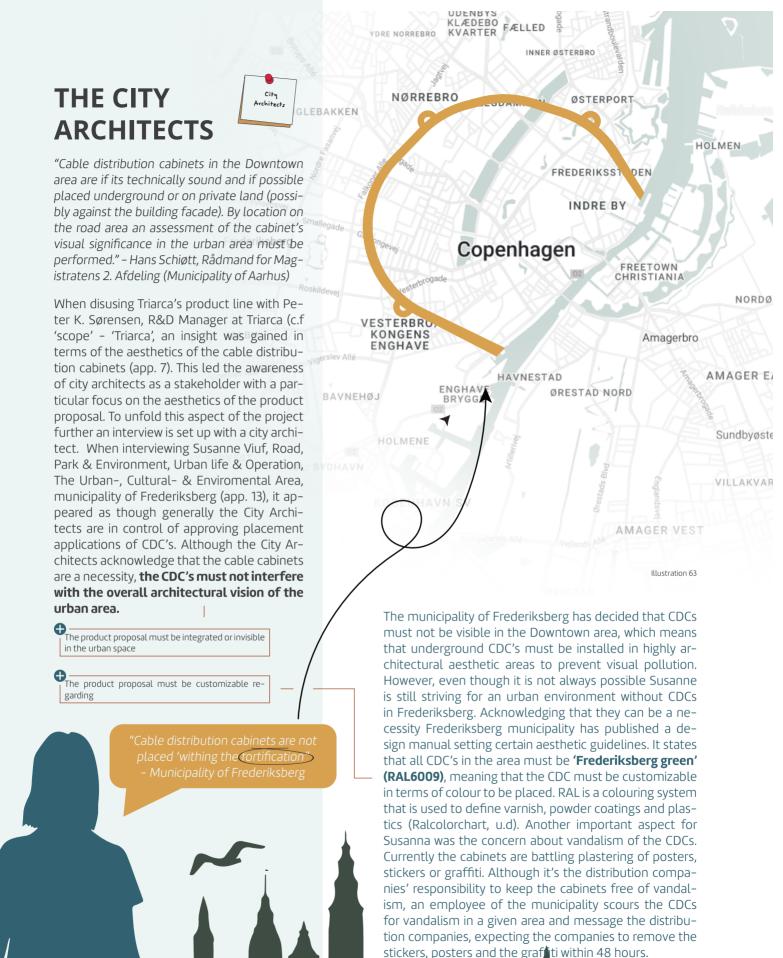
"Every company has their own design inside the cabinet. We like the new (Triarca's model) because it's a lot lighter than the AAB, even though we have extended the cabinet by 1 meter. Also, its faster to install the cabinets in the fuses." – Bjarne

"Extension of cabinets is only the solution for countryside cabinets." - Biarne



Leakage current is the unintentional flow of electricity through conductive materials. To prevent leakage current different product categories, have different ratings referred to as classes. A cable distribution cabinet is categorised as a Class II product. (Sunpower electronics, n.d.)

An isolation class of II means that the user is protected by at least two layers of isolating material. For the CDC's this 2nd layer of protection is the non-conductive coating. A double isolation class is indicated by a double square symbol as seen on illustration 62 (Intersafe, 2019).



PAGE 44

#### **CASE STUDY: STREET FURNITURE**

To gain a better understanding of vandalism, a case study was done. It explored a popular urban area in Aalborg. Found in the urban area is street furniture. These are typically designed to improve the urban environment by providing socializing, shade, shelter or greenery (Miko Engineering, 2024). When establishing a general understanding of the commonalities among these, it was found

to be the colour palette of natural shades such as: brown, gray and black is favored. This palette of colours blends into the environment so focus can be on function for those who need it. The design language becomes numb trying to remain neutral in the larger urban picture – it becomes a "non-design" aimed to not stand out. (app.14)

Non design is defined in this project as: The process of designing products that provides no aesthetic value to its surroundings and is visible only to these who need to interact with it.



An example of non-design related to the project is the shape of the cable cabinet. During the initial sketching rounds (c.f. 'The Initial Approach'), different shapes of the CDC were explored. Although no conclusion to whether a round or oval shape was 'the best', **the resemblance to garbage bins made it apparent as to why these shapes weren't an ideal**. Currently, the cable cabinets are a stand-alone shape in the urban environment (illustration 64) and combined with a triangled interface (c.f. 'Understanding the problem' - 'Cable Distribution Cabinets') the cabinet are easily recognized by electricians and electrical fitters.

When looking at vandalism, illustration 64 showcases that generally flat uninterrupted surfaces are the main target of vandalism. In addition, ridged or busy surfaces are mostly left out. Posters and stickers are commonly found on flat surfaces where the message of the sticker or poster is uninterrupted whether it's a flat surface or rounded surface with a big radius. Furthermore, when evaluating the research, it was found that the height of the current cabinets serves as a stool apart from delivering power to the surrounding building (Bugosciga, 2021), so exploring different heights may be beneficial for preserving the lifespan of the CDC.

The product proposal must not resemble other types of street furniture

#### **DECONSTRUCTION OF A CDC**

During the interview with N1's electrical fitters the damaged Triarca Trilite cabinet were obtained (illustration 66). Likewise, the ABB Combi-line cabinet from Trefor (illustration 65) were obtained after the visit. This information corresponds to insights gathered from Trefor (app 6 & 12) and Triarca (app. 7) that showcased Combi-Line and Trilite as being the trending cabinets among distribution companies. When making a quick visual inspection the team observed that they differed greatly in design language, material and interaction. Therefore, a comparative analysis is performed to identify similarities and differences between the cabinets. To do this each cabinet are de-

constructed into components providing insights while reflection-in-action (Dorst & Cross, 2001). To get an initial overview of the two cabinets each part were noted alongside material if known. On illustration 65 & 66 an overview of the deconstructed cabinets can be seen. The ABB cabinet was constructed from 148 components while the Triarca cabinet used 72. For a complete overview of the components, production methods used, and materials see appendix 15–16. The goal of this process is not to understand every step of the production process but rather to observe differences between the two cabinets.





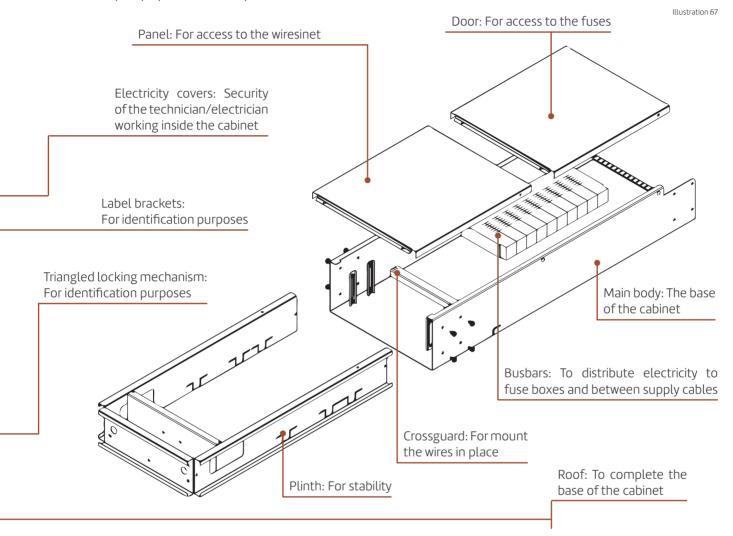
#### **Key takeaways**

A notable difference between the two cable distribution cabinets is that the ABB Combi-line cabinet were obtained with fuses and cables while the Triarca Trilite only included busbar system. Due to a variation in material the two cabinets have been produced differently. The Combi-line is made from extruded fiberglass polyester while the Trilite is made from aluminum. The trilite body, panel and door is made from sheet metal that are cut either with laser or waterjet and then bend into the correct shape. The Combi-line extrusion has an integrated rail system where other parts can be connected to.

Some of the differences between the two cabinets are:

- The triangular locking mechanism. Combi-line use a bolts while Trilite is a 90 degree cam lock.
  - The Trilite is faster to lock but less rigid and durable.
- Cables are attached directly on the busbar in ABB while it goes through a fuse box on Trilite.
- The Trilite cabinet has greatly reduced risk of touching the busbar but requires larger components.
- The number of joints in the ABB cabinet is way higher than the trilite since each supply cable has multiple components where it connects to the busbar.
  - Rivets are more used on the ABB while the triarca uses bolts.

Although the components of the two cables cabinets look different, it is found that the function is the same, which can help us pinpoint what component is the foundation of a cable cabinet:



#### The electro-mechanical interior

After the two user visits and the deconstruction of both CDC's the team decided to keep the existing infrastructure of the CDC's electro-mechanical interior and instead focus 100% on waterproofing the cabinet itself. This choice of project direction was made based on three factors: 1) The team evaluated their design competences were better utilized 2) Redesign the fuse switch, busbars etc. required a deep understanding of electricity which would take too long to acquire. 3) If a successful waterproofing of the cabinet could be done a redesign of the cabinet were not needed. From this point forth the team will therefore use the Triarca Trilite interior and its dimensions as the basis for new concepts. The Triarca Trilite is chosen since it was the cabinet chosen as replacement during both visits (c.f. 'The Electrical Fitter'). It is therefore

assumed that the design is optimized for the current infrastructure.

#### The Board 2.0

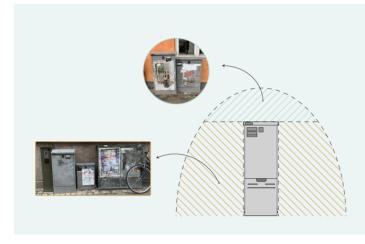
After deconstructing the two cabinets the team realized that besides interacting with each other and the cabinet some stakeholders also interacts with different parts of the cabinet. Therefore, a fifth aspect is added to the board being the CDC. The fifth space is divided into two different aspects. One is the CDC as a product. The other are the seven different components: Base, Panel, Door, Lid, Locking mechanism, Plinth and Interior. This information expands upon the understanding of the cable distribution cabinet from Chapter 1 giving both insights in material, components and function.





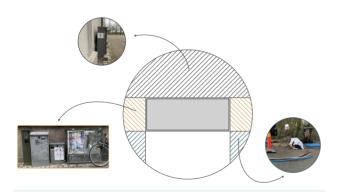
#### **DEFINING THE WORKSPACE**

The workspace describes the immediate area around the CDC where it can take up space, either through physical presence or active movement. The workspace is perceived from three perspectives of the cabinet, the front, the side and the top, shaped by knowledge of parameters Electrical fitters' workflow and urban context (app. 11, 12, 14). By visually determining the workspace from known parameters, development decisions regarding the proposals characteristics in an urban context can be supported. Furthermore, the solution–space can be narrowed down in relation to interaction making the next ideation session more tangible.



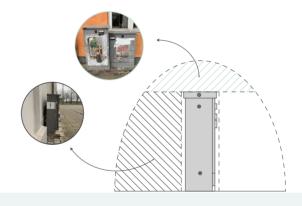
#### **Front View**

Observing the CDC from the front, the immediate adjacent area to the cabinet can be crossed out as possible maneuver space, as CDCs are often placed in rows ('understanding the problem' - 'Cable distribution cabinets') (app. 17), also including other variants of installations cabinets such as TV and internet cable cabinets. When placed in city areas, CDCs can often be seen placed below windows of residential buildings, limiting the height of the CDC as well as the workspace of the electrical fitters in a vertical axis.



#### **Top View**

As observed from the front view and side view, the CDC is limited to its immediate adjacent area and its backside. From this perspective, the electrical fitters 'tool space' can be observed and marked in the maneuver space, adjacent to the immediate workspace of the front.



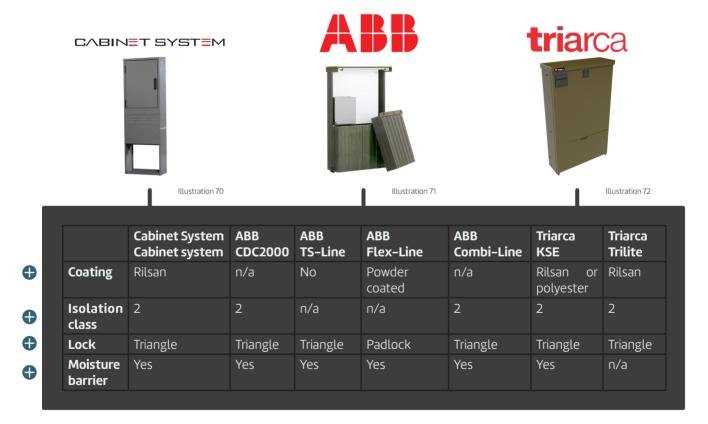
#### **Side View**

As observed in front view, the CDC is limited in height due to urban placement. In the urban environment, CDCs are placed with their backside against the walls of buildings, leaving the front as a possible workspace.

From a front view of the CDC, the workspace is locked to the area of the cross-section of the CDC itself. From a side view of the CDC, it is open on the front side. From a top view, the workspace is open to the immediate front of the CDC. While the areas showcase possible limitations to the physical dimensioning of the CDC a more interesting point is how the workspace influences the interaction between electrical fitter and CDC. By determining workspace, conclusions regarding sub-solutions can be made. Showcased on illustration 69, sub-solutions interfering with a crossed-out space are dismissed.

#### **MARKET ANALYSIS**

During the interview with Trefor (c.f. 'Understanding the problem' - 'Understanding the stakeholders') Per Sørensen mentioned the three manufacturers of CDCs in Denmark which are primarily used by them and other distribution companies. Triarca was one of these companies and are also the Trefor's supplier and was therefore approached earlier in the process. Besides Triarca there are also ABB and Cabinet Systems in Denmark. Furthermore, the results from the deconstruction of the cabinets showed a vast difference between designs. To gain an understanding of the market today and what similarities there are between cabinets a comparative analysis is therefore conducted. The analysis involves seven different product families from the three manufacturers. One from Cabinet System, two from Triarca and four from ABB. When analysing at the seven products (app. 18) from illustration 70-72 some similarities can be observed. The products are made from three materials. Either aluminum, thermoplastic with fibre glass or stainless steel/galvanized steel. To prevent the surface being conductive most are coated. Either with Rilsan made from Nylon or polyester giving them isolation class II. The standard today is to use triangular keys for either locks or bolts to lock the cabinet. None of the cabinets scores higher than 44 on an IP Code which correspond with waterproofing being an issue on existing cabinets. However, a moisture barrier is a common trait to prevent moisture from the ground and small animals entering. Ventilation exists in some products either in the top or on the door. Triarca and cabinet systems seems to value anti-graffiti surfaces and texture highly why ABB has less of a priority on it. Colour is dependent on the individual product, but some are fully customizable.



#### How will we differentiate?

When looking at the cabinets today their goal is to be lightweight, durable, safe and cheap. During the Triarca interview (app. 7) it was mentioned that whether they win or lose the contracts for the different distribution cabinets often comes down to the smallest of price changing thus implying that price is the primary competitive aspect. The value proposition for the product proposal however is different from those of cabinets today. Instead of focusing on price-performance the new concept will focus on minimizing TCO (Total cost of ownership) during its lifespan. The goal is to provide an insurance for the distribution companies where a new cabinet would be cheaper than changing an existing multiple times due to water damage while also reducing manpower needed for maintenance. This has led to the following value proposition: **To provide waterproof cabinets that ensure a reliable power supply during flooding.** 

### WHY CAN'T WE JUST?

During development ('Understanding the problem' - 'Initial direction') certain ideas arose and were discarded among the team members as they were deemed "bad ideas". Some of these solutions observered to be used in the real world, however. One of those covers up the cabinet (illustration 75) and extends the cabinet (illustration 81) ('The Electrical Fitter). To better understand why these solutions were discarded as bad ideas, a step back was taken in the design process. The question of "why not use this solution/principle" was asked with the goal of understanding the solution-space. The following section describes the most prominent 'why not'-scenarios:



#### Illustration 73

Illustration 74

#### **Grouting the** openings closed

Taking inspiration from Niels, why not just grout the openings closed before each flood? This solution is found to be a coping strategy instead of a solution to the problem. Grouting requires a lot of manpower and time due to the number of vulnerable cabinets in Denmark. In addition, it would be costly to the distribution companies. A major concern with this kind of solution will be the difficulty of opening the cabinets again.



Illustration75

Illustration 76

One of the distribution companies' current solutions is to try to cover the cabinet before an incident. Illustration 75 shows an attempt to cover the cabinet with a barrel and 11 sidewalk tiles. In addition, the technicians pumped the barrel with air to create pressure to keep the water out. Illustration 76, showcase the inside of the cabinet and where the water level ultimately stopped. The attempt ultimately failed due to the barrel not being heavy enough to withstand the pressure of the water while also not being airtight.



Illustration 77

Illustration 78

#### Raise the cabinets

Taking inspiration from other counties, raising the cabinets to the utility pole would be a viable and permanent solution. Although Danish Standards only include guidelines for the current distribution cable cabinets, the time, cost, and the effort to rewire the entire Danish power grid will be a major operation. In addition, the context of the current placements of cabinets does not always allow for these kinds of changes.



#### Illustration 79

Illustration 80

# Place the cabinet inside the house

This strategy seemed like a good idea to fulfill the city architects desire for removing the cabinets while also safekeeping them from flooding. However, since multiple residents often are utilizing the same cabinet, this would mean a huge restructuring of the power grid is necessary which would be expensive for all parts. Furthermore, the cabinet must be accessible for the distribution companies, which would not be possible if they were to be placed on private ground.



Illustration 81

Illustration 82

# **5** Extend the cabinet

The manufacturing companies' solution for the flooding problem is to extend the cabinets. When purchasing a cabinet, the customer can request an extra component, extending the cabinet by either 0.5, 0.75 or 1 meter. Due to the various cabinet placements in different contexts, shown on illustration 81, an extension does not always allow for this type of solution due to blocking windows or the cabinets being placed in bushes. This was also verified during the CDC case study in chapter 1 and when establishing the workspace of the electrical fitter. Research shows residents being unhappy with this solution because the cabinet blocks the view (Jørgensen, 2014). Even though this is the best currently solution, it is a coping strategy, and the cabinets can only be extended so far before inevitably flooding occurs.

#### **Evaluation**

Evaluating the different products, it became apparent that three things were of importance for a product proposal. Firstly, the proposal must not be a coping strategy but instead a permanent solution that solves the flooding problem. Secondly, the proposal must fit into the existing infrastructure otherwise it will not succeed in implementation. And lastly, it must not require manpower present before/during each incident.

#### **DESIGN BRIEF 2.0**

#### **Problem Statement**

How to design a waterproof cable distribution cabinet that ensures security of supply, during flooding, while fitting into the established infrastructure of the distribution companies and Danish power grid.

#### **Target group**

Distribution companies.

#### Value proposition

To provide waterproof cabinets that ensure a reliable power supply during flooding.

#### Stakeholders:

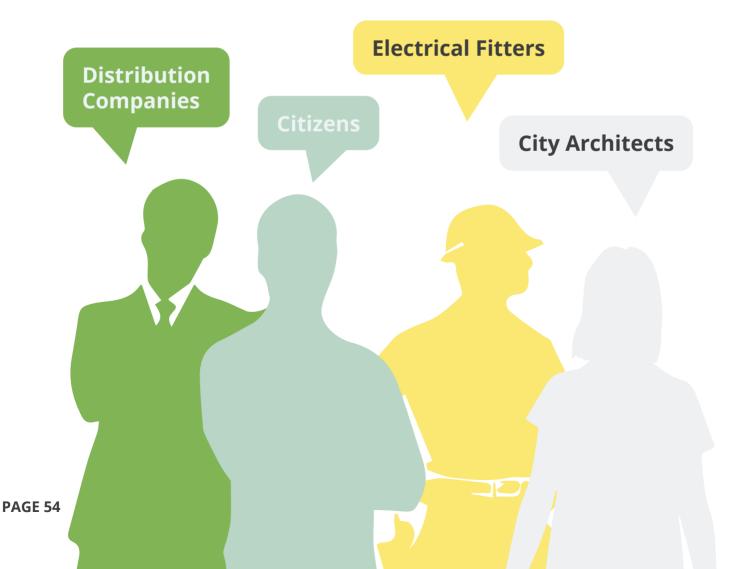
#### **Unique selling points**

How to design a waterproof cable distribution cabinet that ensures security of supply, during flooding, while fitting into the established infrastructure of the distribution companies and Danish power grid.

- A waterproof solution
- A design that blends into the urban enviornment
- A proposal that maintain and improve upon existing interaction interfaces

#### Goal

To provide consumers like Niels and Line with agency during flooding incidents by maintaining the functionality of cable distribution cabinets giving them the resources needed to fend off flooding, while also designing a solution that integrates the product into the environment without compromising the workflow of the user.



# **Functionality**

- The proposal must be able to withstand future, more severe flooding incidents p. 14
- The surface must not be conductive p. 24
- The product proposal must not corrode
  - The product proposal must be resistant to salt p. 25
  - The product proposal must be resistant to all types of water p. 28
- The product proposal must fit into the existing infrastructure of the power grid p. 28
  - The product proposal must be integrated or invisible in the urban space p. 42
  - The product proposal must be customizable regarding colour p. 42
- The solution must fit the standards dimensions p. 28
- The proposal must prevent moisture inside the cabinet p. 49
- The product proposal must have the isolation class I p. 49
- The front door must not intersect with the terrain p. 40
- The ID must be transferable from the old design p. 40
- It must be possible to lock the cables in place p. 40
- The busbars must be fixed into place p. 40
- It must be possible to remove the entire front face p. 41
- Must have a triangle interface lock p. 49
- The panel handle must be above the ground p. 40



- The product proposal must be non-intrusive in the urban space p. 28
- The product proposal must be applicable in all contexts p. 22
- The proposal must function without needing permission in the build-up phase off an incident p. 28
- The product proposal must not encourage vandalism through its shape or surface p. 43
- The product proposal must not resemble other types of street furniture p. 43



- The solution must be labelled
  - Manufactures name or trademark
  - Type designation or identification number or any other means of identification
  - Means of identifying data of manufacture
  - Rated current of the assembly
  - Rated voltage of the assembly
  - Rated frequency of the assembly
  - IEC 61439-X (X shall be defined)
- The ambient air temperature must not exceed +40 degrees (average over a period of 24h does not exceed 35 degrees. And under -25 degrees.



- Must be able to operate in the temperature interval
   -25 to 40 degrees Celsius
- Must be able to operate in 100% humidity in -temperature interval -25 to 27 degrees Celsius
- Must have an IK code of 10
- Must have an IP code of 34D+
- Must have a lock that prevents the public from accessing the interior
- Must be UV resistant in temperate climates
- The cables must be easily connected through the front
- Cables must enter the cabinet from below

# CHAPTER OBDEVELOPMENT A NEW TAKE ON CABINETS

#### **SUMMARY**

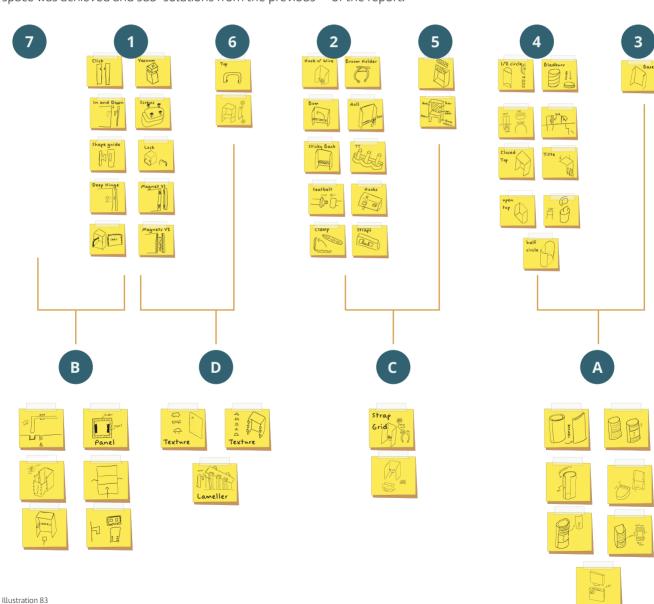
The following chapter is an extension of the development phase converging (Dubberly, n.d.) based on the information gathered, and covers a new method regarding concept development. A combinatorial design approach (Pahl et al., 2007) is utilized to discover two different concept directions. Throughout the chapter a more hands-on approach is utilized changing the team's mindset towards reflection-in-action (Malinin, 2018) and a build-measure-learn loops (Ries, 2011) where prototypes are built, and test performed. The chapter concludes by closing the development phase by determining the concept of the cabinet based on expert feedback.

- 3.2 A Combinatorial Design Approach
- 3.3 Mini Tests
- 3.4 Feedback An expert's Opinion 1.0
- 3.5 A Competition

#### A COMBINATORIAL DESIGN APPROACH

Based on the additional information gained in chapter 2 (Exploring the solution space – Development), the method of problem slicing (Dubberly, n.d.) ('Chapter 2 – The Initial Design Approach') was resumed, but with a different approach, the goal being to converge towards a product proposal. A combinational design approach (Pahel et al., 2007) was attempted based on the insights from each stakeholder, leading to a different categorization of the sub-solution (Dubberly, n.d.) from the first problem slicing attempt. From the 2nd attempt, seven slices were drawn, each showcasing different methods of solving the given slice (see illustration 83). With the information gained from chapter 2, a narrowing of the solution space was achieved and sub-solutions from the previous

slice could be eliminated (see illustration 83). By applying a combinatorial approach, the development phase became more tangible since the focus area was narrowed down to two different slices, for example: A) The front edge must act as an edge for the door combined with full access to the interior. This step was then repeated combining the slices two and two. When moving on to the next step in the combinatorial process the team experienced stagnation. Trying to combine further combine the principles into one or more concepts became intangible due to a lack of physical understanding of the different aspects of the principles. This is something that is going to be explored further in the next section of the report.



#### **PROTOTYPING 1.0**

To create a physical understanding of the principles described during the combinatorial approach the team opted into rapid prototyping (Schrage, 2003) switching to a 'reflection-in-action' (Malinin, 2018) mindset while making concept development more tangible. The prototypes made were divided into; Locking mechanisms, Attachments and 1:2 prototypes.



Illustration 84

#### Attaching the door to the panel

For the attachment of the door to the panel two concepts were made both inspired by the existing solution seen on the Triarca Trilite cabinet (illustration 84)

Illustration 85

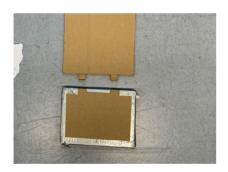






**Prototype A:** A modification of the existing solution where pressure is created when tilting the door (illustration 85) onto the 90-degree section of the panel fixing the door in place and sealing the cabinet.

Illustration 86





**Prototype B:** A cutout in the panel allows for two tabs mounted on the bottom of the door to attach to the back of the panel creating a seal between the parts

#### Attaching the door to the cabinet

Illustration 87







**Prototype C:** (Illustration 87) shows a concept where cutouts are made into two flanges on the cabinet allowing for hooks to enter locking the door in place.

Illustration 88







**Prototype D:** (illustration 88) is a concept where the door and panel are slid into the cabinet from the top and downwards creating a flush surface and meeting with a recess and tab that extends from side to side like prototype B.

#### Attaching the lid

For the lid attachment prototypes of three principals were made.

Illustration 89





**Prototype E:** (illustration 89) is made up of two parts. The lid and a mechanism that allows the lid to lock in place. A spring is placed inside the box on the underside of the lid which folds in when pressing in on two buttons placed on the sides of the lid. The design resembles that of a door and requires minimal interaction when placing the lid while more steps are required to release it, allowing to accommodate for electricians and electrical fitters to easily close the cabinet multiple times during a scenario.





**Prototype G:** is a lid with an integrated hinge that allows the top to be opened when interacting with the cabinet.

Illustration 90

Illustration 9

**Prototype F:** presents a solution where a frame is placed on top of the cabinet creating a surface for a squared lid to be placed upon. The frame was iterated upon multiple times, and on illustration 90 a variant can be seen that facilitates the attachment of a gasket.

#### **Locking mechanisms**







Illustration 92

Illustration 93

Illustration 9

For the locking mechanism, two variants of locks were prototyped. The principle for both is a cam that is moved behind a flange on the cabinet. Prototype H achieves this through a slider, inspired by the ABB cabinet while prototype I (illustration 94) uses a 90-degree turn lock.

#### 1:2 scale models

After building prototypes A-I and learning through multiple build-measure-learn loops (Ries, 2011) two 1:2 prototypes were built (illustration 95-96) to gain an understanding of the interaction between different parts when working in a larger scale



Illustration 95

**Prototype 1 (illustration 95)**: is a cabinet designed from one sheet where the sides are bent alongside a flange on either side. On the bottom and the top, a frame is attached creating an offset edge that allows for a gasket or O-ring to be placed connecting to all four edges of the door and panel.



Illustration 9

**Prototype 2 (illustration 96):** is designed to avoid joints on the lid by bending a cardboard to create the top, and sides alongside two internal walls that also covers parts of the bottom. The trade-off for this design is that the back of the cabinet must be attached separately. Prototype 2 also address the waterproofing of the cabinet differently and is made with the ambition of making it airtight to prevent water from entering. This will be explained alongside two other concepts in the following section.

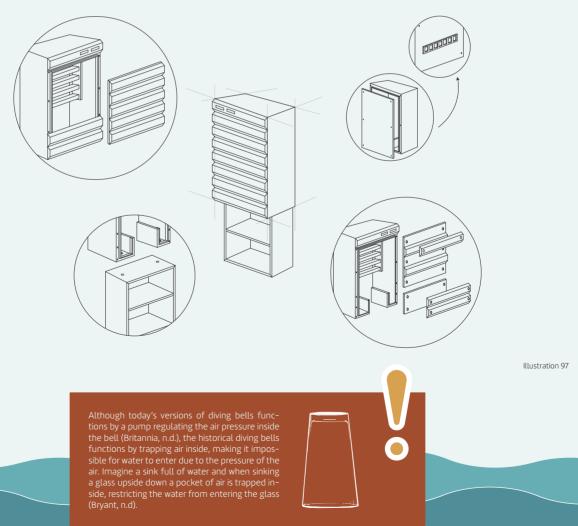
#### THE CONCEPTS

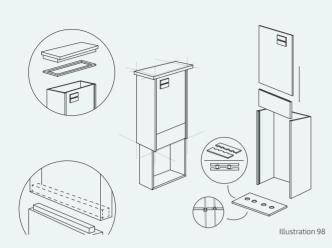
After combining the principles into more detailed solutions and creating prototypes a new brainstorm session was initiated based upon the previous ideas. This led to three concept directions: 1) An airtight design and (2) A waterproof design 3) A sliding top.

# **01** An Airtight Design CONCEPT

The airtight concept builds upon prototype 2's design. The concept includes an airtight design based on a principle that is mostly seen in diving bell designs. Although the distribution companies currently try to prevent water inside the cabinet ('Chapter 1 – 'Understanding stakeholders & experts'), this concept allows a small amount of water to enter in between the walls. The idea is to take control of the water, deciding how and where it enters the cabinet in case of flooding, thus redefining the team's understanding of 'a waterproof' solution.

The half walls inside the cabinet are intended to control the water level, ensuring the water can only rise to a certain point. The complicated process of sealing multiple surfaces at different assembly points is simplified thus reducing potential sources of errors. By applying the diving bell principle in the design, an open bottom can be achieved making cable entry easier. Something of relevance when considering the fluctuating number of cables in each current cable cabinet already placed.



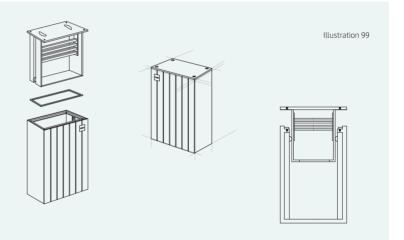


# **02** A Waterproof Design CONCEPT

The waterproof concept builds upon a fully sealed cabinet. It is constituted of five components that have to be attached to each other on site. A base which is placed in the ground, a bottom plate which allows for cable entry, a panel, a door and a lid that fixates the door in place. The concept revolves around cables entering either through cable glands or triangular rubber attachment. When the water rises the pressure of the seal is amplified securing the integrity of the cabinet. The cabinets base is built on prototype 1's design and aims to create four edges around the cabinet, being the bottom, top and two flanges that a gasket can be attached to.

# **03** A Sliding Design CONCEPT

The 3rd concept challenges the current interaction and interface of the CDC today. Instead of removing the front door during use the top of the cabinet is placed on sliders and can be moved up to access the interior. This design goes against the discoveries regarding the workspace (c.f. 'Exploring the solution space' – 'Defining the workspace') and even though the concept in certain aspects weren't feasible, showing a radical design to the users would give valuable insights.



In order to choose a concept direction, feedback from the stakeholders was needed. The three directions present different ways to waterproof the cabinet but greatly differentiate in their way of doing it thus changing the workflow of the electrical fitters. A new meeting was therefore established to gain feedback on the concept directions.

#### **MINITESTS**

To better understand the three project directions, a set of mini tests were conducted. Firstly, a test of the airtight solution was done in mini scale to validate if it was possible to prevent water from entering with an open bottom. Secondly, some of the sealing methods considered for the front door were tested since both concepts relied on an opening in the front.

# Airtight solution TEST

#### **Preparation and hypothesis:**

A quick test of the airtight solution was conducted by 3D printing the concept on a scale of 1:5. The test checked if water would flood the cabinet's interior from below. A seethrough acrylic sheet was then grouted to the front of a 3D printed model to seal the edges and to ensure an airtight model left only one point of entry for air. Before the experiment could take place, the model was filled with water to ensure no leaks would occur.

#### The test:

To simulate a CDC a container was filled with soil. The 3D model was then placed before adding water. When adding water, the model started to float to the top before eventually tilting due to **buoyancy** (Illustration 102). To prevent this from happening a lid was carefully placed on top of the container to hold down the 3D model. The model was then left overnight.

#### The result:

Although the experiment progressed as hoped and no water was present inside the cabinet and additional concern the design emerged. When inspecting the model, condensation on the acrylic sheet was clearly visible (see illustration 103).



Illustration 100



Illustration 101



Illustration 102



Illustration 103

# **02** A sub-solution TEST

When discussing ranking the different sub-solutions for the cabinet's front door, it was decided to conduct mini experiments to hopefully narrow the potential solutions. Two types of barriers were 3D printed and then tested to see if water would penetrate the seal.

#### **Sealing method 1:**

The first test aimed to examine how a sealing between the door and the base would function. A box resembling the cabinet was made (illustration 104) with two flanges. A door was then designed that would create a flush surface while allowing for sealing tape. When applying equal pressure on the sides, the sealing would deny water from exiting the box (illustration 105). However, when filling the box with water a leak was discovered between the bottom of the door and the bottom of the box. Due to 3D print warping (edges of the print lifting during the printing phase) occurred, it compromised the integrity of the test, and it was discarded.

#### **Sealing method 2:**

A slip of rubber is placed between the two components that resembles the joint between door and panel and pressed down into the box, seen on illustration 106. When a downward force is applied, the components are squished together, prohibiting the water to get though. The barrier was placed in a container and all surrounding edges were sealed with sealing tape. One side of the barrier was then filled with water. The experiment was left alone for approximately 10 minutes. After some time, water slowly began to leak onto the other side of the barrier. When identifying where the leak was coming from, it was found to be a gap in the tape used. The sealing between the two components, however, functioned.

#### **Evaluation:**

When evaluating the three quick tests some key takeaways were identified. The first test showed that buoyancy and condensation could be a problem when the cabinet is sealed and must therefore be investigated further. When looking at the two sealing experiments it was concluded that the tests only evaluated whether or not the principle worked. Since these principles were observed and inspired from current solutions, the sealing method is already confirmed to be viable. Instead, a sealing method test must look at the concept holistically so it can be tested in relation to its use scenario.



Illustration 104



Illustration 105

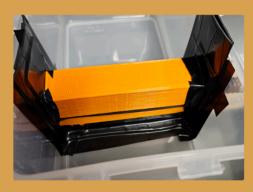


Illustration 106



Illustration 10

#### **FEEDBACK - AN EXPERT'S OPINION 1.0**

When deciding the direction of the concept, an expert's opinion was needed and the N1 electrical fitters were contacted again. In addition, an interview was also set up with an electrician in the team's network since it had been discovered that electricians also work with CDC's. For both interviews prototypes and sketches were brought.



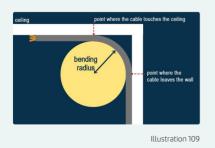


#### Interview with electrician

The interview with the electrician (app. 19) was a semi-structured interview (Delve, n.d.) out of context limiting the information to acting-out and situated-use (Bagger & Sperschneider, 2003). During the interview the team obtained a supply cable (illustration 108) in addition to the cables previously gathered (illustration 24) giving an understanding of the rigid nature of supply cables. The interview also provided the following insights:

- A CDC might be opened multiple times each time an electrician or fitter interact with it since they cannot leave them while being open.
- The cables must be static for the connectors (illustration 108) inside not to break over time.
- The size of supply cables is increasing due to increasing demands (e.g. electrical vehicles).
- The cables are buried up to 70 cm below ground. -
- The bending radius of the cables are important for not damaging them.

To not damage the connectors inside a cable it is important not to bend it with too small of a radius (illustration 109). Most cables have an assigned radius often defined as diameter multiplied by a factor often between Dx4 and Dx16 (Nexans. u.d.).

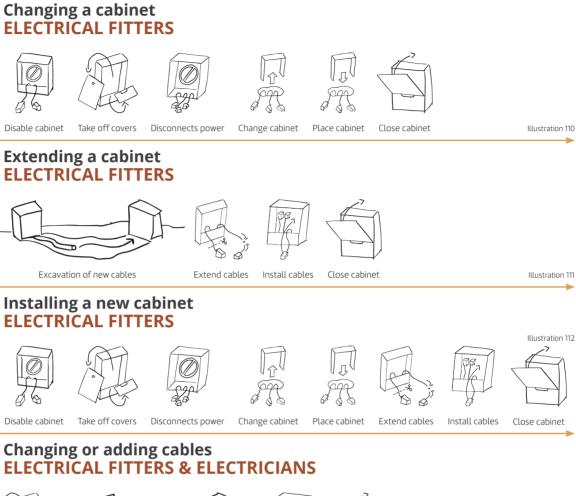


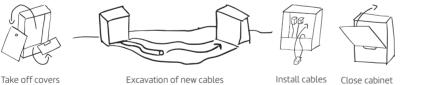
The product proposal must not exceed 70 cm below ground

#### **Scenarios**

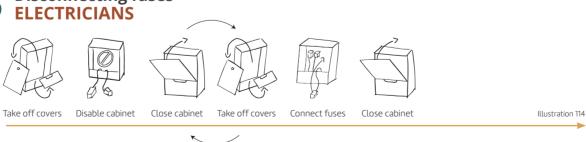
Based on the interview with the electrician and the electrical fitters (c.f. 'Exploring the solution space' – 'The Electrical Fitter') five scenarios were illustrated. These each describe what task(s) and interaction(s) the user experiences during their work.

# **Changing a cabinet**





### **Disconnecting fuses**



By comparing the five scenarios it becomes clear that the removal of the front door l is a guaranteed interaction whenever someone interacts with the CDC. The panel is removed in every scenario except in number 5 and as such is also frequent interaction between user and product and the same is true for attachment of cables. For scenario 1-3, which is the fitters' tasks solely, the attachment of fuse boxes and placement of cabinet also occurs alongside potential extensions of cables in scenario 2.

Illustration 111

Illustration 113



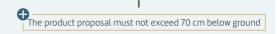
## **Review of the airtight concept**

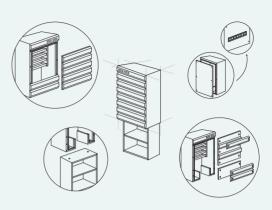
"In terms of workflow, the concept is very nice. Although I'm concerned about electricians not closing the cabinet correctly." – Jeppe Filt, Electrician.

"You have to gradually switch between them [Speaking of tightening wheel nuts] to ensure the wheel is placed correctly so you would have to number the screws if using screws for the front door] – Jeppe Filt, Electrician.

"The cables only get bigger, and the number of cables is increasing, so if you minimize the space in the bottom, it might be a problem. We don't want to stack the cables on top of each other." – Mads Erik Eriksen, Electrical Fitter

"If the cables are attached properly, the cabinet won't go anywhere, I don't think. Also, typically gravel is placed in the bottom of the plinth." - Mathias Kodahl Jensen, Electrical Fitter





#### **Our evaluation**

#### Opportunities

- Accommodating for the changing number of cables in each cable cabinet.
- Installing future cables won't be an issue.
- No interfering with the current workflow.

#### Concerns

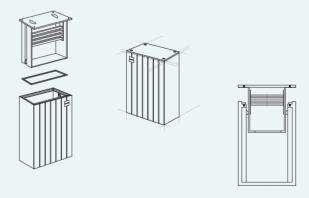
- Buoyancy when flooded.
- Carelessness when closing the door or the panel.
- Condensation in the cabinet.

# Review of the sliding concept

The cables must not be stressed and bend, otherwise the connectors inside might break" – Jeppe Filt, Electrician.

"It will be too difficult to open the lid due to all the rigid cables that are connected to the interior" – Jeppe Filt, Electrician.

"It's a super nice concept on paper – Would be better ergonomics from the increased height but it wouldn't work in praxis." – Jeppe Filt, Electrician



#### Our evaluation

• After discussing the product proposal with the electrician alongside the previously known issues (c.f. 'A combinatorial design approach') the team decided not to pursue this direction further and therefore didn't discuss it with the electrical fitters.

#### Review of the waterproof concept

"The cable glands sit at the bottom of the cabinet, creating a blind working area and that can be a problem" – Jeppe Filt, Electrician.

"With cable glands you can tighten them to much twisting the gasket and ruining it" – Jeppe Filt, Electrician.

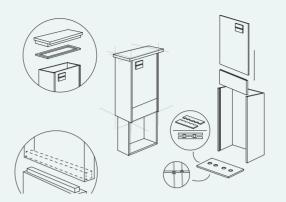
"I see most potential in this concept. Getting cables through individual holes would be no problem." – Jeppe Filt. Electrician

"We currently tilt the cables inside the cabinet, because it's the easiest." - Mads Erik Eriksen

"The electric supply cables are non-flexible; you cannot bend it. It may be possible to bend the power cables running into the house." – Mathias Kodahl Jensen

#### Choosing a concept

The feedback from the electrician and electrical fitters were contradictory on certain aspects when asked about the favorable concept. The electrician favoured the waterproof concept while the electrical fitters preferred airtight. When looking at the five scenarios this feedback makes sense. The electrician works with less rigid cables and do not have to deal with inserting the fuses boxes. Overall, they perform fewer interaction types than the fitters do however, they perform them more frequent. The argument for choosing a waterproof design was to accommodate for the number of times the electricians must open or close the cabinet while working. A potential mismanagement when interacting with the cabinet could occur and the waterproof design is more forgiving in that sense. It was chosen to move forward with an airtight design due to it accommodating all types of interactions better. It allowed for the addition of cables after the initial installation. Furthermore, it also had fewer potential points of failure with no bottom and an attached top meaning only the door and panel had to be airtight when locked. Overall, the concept disrupted the current workflow of the fitters the least possible making it ideal. However, based on the feedback of the two interviews the concept was adjusted also combining some of the features of the waterproof concepts. Illustration 115-116 shows a new mock-up. The base of the cabinet was changed to that of the waterproof concept thus simplifying the production. A new design was made for the gasket. Instead of the frame from the waterproof concept



#### **Our evaluation**

#### Opportunities

- The point of failure is not critical. Compared to an airtight design, the door and panels are not critical points of failure.
- Utilizing existing solutions within electrical sealing.

#### Concerns

- The number of joints between sealings and cables creating a lot of weak points.
- Entry for the supply cable.
- Adding additional cables.
- The workflow when installing the cables.

a recess is made for the gasket (illustration 116) by bending the flanges on the front of the cabinet while also extending one edge of the lid. The main design challenges for the new concept were the sealing between lid, door, panel and base alongside the joint necessary for the recess when it goes from base to lid (illustration 116). Something that will be explored in the following chapter.





ustration 115

Illustration 116



# COMPETITION

During further research of distribution companies in Denmark the team gained access to documents (app. 20) from a ruling between Triarca and Nexel, the owner of the distribution companies Radius and Cerius on Zealand (see illustration 17 in 'Chapter 1' – 'Cable Distribution Cabinets'). Triarca had complained to The Danish Complaints Board for Public Procurement (Nævnenes Hus, n.d) that Nexel chose ABB as their supplier from 2023–2028 during a tendering process since ABB should have been disqualified. In the document a set of requirements were set to the supplier in order for them to be able to win the contract. When evaluating possible contenders Nexel rates the proposal as follows: 60% price, 30% tests and 10% QHSE (quality, health, safety, environment). Based on these requirements the following product specifications could be made:

- The cabinet must be able to be coloured based on the RAL system.
- The cabinet should be coated with anti graffiti.
- The cabinet must be designed to prevent condensation around the interior.
- Maximum height above ground: 900mm.
- Maximum depth: 280.
- Must have identification of class II insulation.
- Must be able to attach 10 characters in the ID holder.
- Maximum weight 40 kg.

Besides the requirements the documents also showed that Radius and Cerius buys 5735 cabinets every year. Comparing this to their total cabinets of xxx an estimate can be made on how many cabinets are being bought in Denmark each year. Cerius and Radius combined has 302.000 (Cerius, n.d. & Radius, n.d.) cabinets out of the roughly 1.1 million (Greenpower, 2019) in Denmark which equals 27.5% of the total number of cabinets. Given the assumption that all distribution buys the same % of new cabinets each year this would set the yearly acquisition of CDCs in Denmark to roughly 21.000 cabinets.

# **DESIGN BRIEF 3.0**

# © Functionality

- The proposal must be able to withstand future, more severe flooding incidents p. 14
- The surface must not be conductive p. 24
- The product proposal must not corrode
  - The product proposal must be resistant to salt p. 25
  - The product proposal must be resistant to all types of water p. 28
- The product proposal must fit into the existing infrastructure of the power grid p. 28
  - The product proposal must be integrated or invisible in the urban space p. 42
  - The cabinet must be able to be coloured based on the RAL system. p.68
- Maximum weight 40 kg
   p. 68
- Maximum height above ground: 900mm p. 68
- Maximum depth: 280 mm p. 68
- The cabinet must be designed to prevent condensation around the interior p. 68
- The proposal Must have identification of class II insulation p. 68
- Must not exceed 70 cm below ground p. 64
- The ID must be transferable from the old design p. 40
- Cable must be fixed next to each other p. 66
- Must be able to attach 10 characters in the ID holder. p. 68
- The busbars must be fixed into place p. 40
- It must be possible to remove the entire front face p. 41
- Must have a triangle interface lock p. 49



- The cabinet should be coated with anti graffiti. p. 68
- The product proposal must be applicable in all contexts p. 22
- The proposal must function without needing permission in the build-up phase off an incident p. 28
- The product proposal must not encourage vandalism through its shape or surface p. 40
- The product proposal must not resemble other types of street furniture p. 43

The requirements from Danish Standards can be found in 'The Initial Design Brief on page 31.

# CHAPTER O4 DETAILING PROVING THE CONCEPT

# **SUMMARY**

The following chapter showcases the initial detailing of the product. The concept is problem sliced (Dubberly, n.d.) into major subsections to be detailed. Due to the integrated nature of the CDC as a product type, multiple themes are addressed and executed in parallel throughout the process continuing with the handson mindset from chapter three. The parallel process of the chapter has been simplified to a linear process in the report where the most essential parts of the concept are detailed first making the process easier to comprehend. The proposal has been detailed through tests, prototypes and expert sparring. The chapter concludes by presenting the product proposal; Nereus.

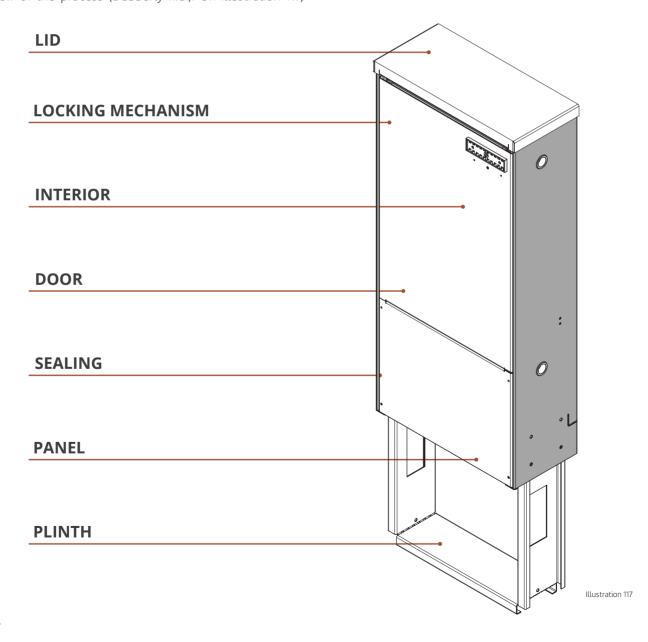
- 4.2 Problem Slicing
- 4.3 Coating
- 4.4 Creating the Seal
- 4.5 How Do We Connect the Door And the Panel?
- 4.6 Defining the Interior Design
- 4.7 Addressing the Buoyancy
- 4.8 How Do We Close Cabinet?
- 4.9 What About Condensation?
- 4.10 Nereus AT46

# PROBLEM SLICING

With an overall concept designed to solve the flooding problem a detailing phase is begun to transform the cabinet from sketch (illustration 117) to detailed CAD model. During the rapid prototyping process ('A New Take on Cabinets' - 'Prototyping') different models were made with the intention of using metal bending as a production method. The specific metal will be specified during material consideration after a design has been made but the initial thoughts using an unspecified metal.

Although elements of the cabinet are very much dependent on each other and it is difficult to break up into small sections, the current concept design is sliced into slightly bigger, but tangible pieces to retain a manageable overview of the process (Dubberly n.d.). On illustration 117,

the design is broken up into five parts: **Sealing, lid, panel/door, interior, plinth and locking mechanism** since these are the main areas where different components interact with each other. The concept will be detailed in said order starting with the sealing since it lays the foundation for the airtight concept and is intertwined with all other aspects. The illustration will be updated throughout the chapter until a complete 3D model is achieved. It should be mentioned that even though not thoroughly explored yet, the design's initial measurement is based on the Triarca Trilite cabinet to have a reference point making the detailing process even more tangible. Throughout the chapter tests and ideations will be conducted to specify these measurements to the product proposal needs.



# **USING COATING TO OUR ADVANTAGE**

In the earlier stages of detailing the concept the question of "How do we ensure, that the CDC is airtight?" was asked. During 'The Initial Design Approach' (chapter 2), O-rings and rubber gaskets were identified as being effective and versatile solutions that can be adapted to a variety of different industrial usages under different circumstances. Utilizing their versatility and ability to be adapted into different scenarios made them ideal for the sealing between door/panel and cabinet. However, it was discovered that during the attachment of the lid, even though not fully detailed, small airgaps would be inevitably which would have to be sealed. The idea was therefore to utilize a coating to cover these gaps while also achieving the requirement of a double insulation class.

#### Rilsan

Because the cable cabinets are placed outdoors, it is important to protect it against the weather, more specifically against corrosion. From the 'Market Analysis' in chapter 2, it was discovered that a Rilsan powder coating was favored by some of the competitors, leading to a case study (app. 21). Furthermore, the market analysis also showed the coating had the ability to be colored with RAL after demand thus fulfilling requirement: 'The cabinet must be able to be coloured based on the RAL system'. Rilsan is a thermoplastic synthetic coating made from castor oil (illustration 118), that is derived from plants. It is a nylon coating that is a cheap and durable alternative to stainless steel (Kersten, 2024) that provides a strong abrasion resistance and resilience (CSI, 2020). Multiple variants exists but for outdoor applications, Rilsan PA11 is the most common. In appendix 21 a more in-depth comparison can be found between variants. PA11 It is more flexible, has a lower permeability, improved impact properties and better dimensional stability than other variants. In addition, this type of coating is light weight and can last for over 50 years (Arkema, 2024), making this coating the top candidate for the product proposal.



Illustration 118

## **Permeability**

Permeability is a term that is used to describe the capability of gas or liquid to pass through a porus material (Cambridge Dictionary, n.d). It is defined as:

"The velocity with which a fluid of specified viscosity, under the influence of a given pressure, passes through a sample having a certain cross section and thickness." – Britannica, 2024

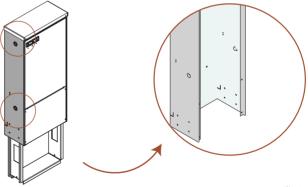


Illustration 119

Rilsan is often applied in a thickness of 0,25–0,5 mm. To ensure a uniform coating four inserts are placed in the based. These are used to stabilize the base during the dip process, which will be elaborated upon further in the production section of the report. Then connecting to both the surface of the lid and base of the cabinet this will create a coating of 0,5–1 mm thus sealing the openings. To further validate the use of Rilsan to coat the cabinet an analysis from Arkema (2022a) showed, that when comparing the permeability with that of PVC plasticized and natural rubber the Rilsan is far superior. A permeability test shows how many grams of gas particles move through the material in 24 hours (app. 21). The results show that 2g of air can travel through the material at 20 degrees pr square meter. This would mean that the coating makes the cabinet practically airtight since the area of open surface is so small and Rilsan is therefore chosen also securing an insulation class of II.

# **CREATING THE SEAL**

With the lid fixed to the base, this only leaves the front door and the front panel to be sealed against the base with either a rubber gasket or an O-ring. In this section different lids will be presented and the question of "how to make an airtight seal between (1) the door and the base? (2) the panel and the base?" (showcased on Illustration 120) will be answered. To start off, the process was slowly moving away from sketches and towards cardboard prototypes applying a build-measure-learn (Ries, 2011) mindset simultaneously with reflecting-in action (Malinin, 2018). The purpose was to better the understanding of how the lid was to meet base. Illustrations 121-124 showcase different methods of how the lid potentially could look like. Additional ideas not presented are listed in appendix 22.

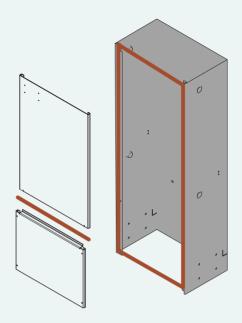


Illustration 120



Illustration 12

This idea builds upon bending a flange on the lid like presented on illustration 121, in order to continue the slits from the base. A rubber gasket or an O-ring is placed in the slit. Upon reviewing, the feasibility of a 90-degree bending radius of a rubber seal was a concern.



Illustration 122

To solve the concern of the 90-degree bending radius, a lid with a rounded flange was attempted. Although the design solved the problem, a new difficulty of connecting the lid and the base arose due to the different shapes.



Illustration 123

In this idea, the lid has a bend flange and three separate rubber seals for each edge. A gasket is placed in the slits on the edges of the base in addition to the lid to ensure the seal won't move when closing or opening the front door. A concern with this idea was the seal on the lid being placed too far back.



Illustration 124

To accommodate for the concern of the gasket being placed too far back into the cabinet in the 3rd idea, this idea ensures that the gasket will be able to stay flush with the edges of the base. Although the joints are now flush with each other, a concern is a potential air gap when operating with separate rubber parts.

During the construction of different lids, desktop research on different materials best suited for the seal was explored (app. 23). Even though it was possible to narrow the material down to two different sealing materials: EPDM and Nitrile, a decision could not be made. Both materials seemed good in an outdoor context, however, the main gap of reliable information was the lifetime of the materials when used as sealing. A meeting was therefore established to gain expert knowledge.

#### Consulting an expert

- The gasket must be produced in EDPM, due to the material being better suited
- The lifespan of an EDPM rubber gasket is approximately 20 years. Due to the
- When showcasing the different lids, the designs with separate gasket joints (idea
- The door and the panal must equally distribute its pressure on the gasket to ensure its integrity.
- A gasket is better suited than an O-ring since it can be shaped to our form.

### **Choosing the gasket**

During the visit to Aalborg Gummivarefabrik, five different types of rubber gasket samples were acquired, shown on illustration 125. In addition to the interview, specifications such as bending radius, price, material type were researched (app. 24) to guide the team in the right direction. It was observed that the gaskets with a clamping profile were around three times as expensive as the ones without. A solid cellular gasket was also acquired but information from AAG showed that it was more prone to damage if over compressed. Even though expensive when comparing the five samples, the rubber gasket chosen was an EPDM cellular rubber clamping profile with steel posts (see illustration125). With a clamping profile it is possible to attach the gasket on both the front and side giving flexibility in the design process while controlling the compression by customizing the cross section. Furthermore, this type of gasket is not dependent on adhesive due to a clamping profile also allowing for easy replacement. The gasket chosen is a recommended Ø16 mm gasket with a bending radius of 20 mm (app. 24) that is a standard assortment gasket for AAG.

### Modifying the design

With the sealing method decided, detailing of the base in addition to the lid could progress further. Another round of rapid prototyping with cardboard and the gasket sample was conducted. Due to the gaskets clamping placement and the wish to have one continuous gasket all the way around the cabinet, the lid was detailed to have a curve with a radius of 20 mm as shown on illustration 126, securing the attachment of the gasket without twisting it. Furthermore, it was decided to change the base flanges (see illustration 127) to accommodate the new lid.



Illustration 125



0 ( 0 Illustration 127

Illustration 126

# HOW DO WE CONNECT THE DOOR AND THE PANEL?

Continuing the journey of detailing the product proposal, the question of "how the connect the door and the panel?" was the next task to untangle. The starting point from chapter 3 was an attachment system inspired by the Trilite cabinet (see illustration 128) where the door and the panel locks together when the door is tilted into place. When designed with the correct tilting angle the hypothesis is that just the right amount of pressure will be applied on the gasket creating a tight seal. For the development of the door and panel, a set of design parameters were set:

- The front panel must act as an edge to the front door.
- The front door must be tilted into place.
- During the tilt, tension between the front door and front panel should increase. The tension is needed to ensure a good compression on the sealing gasket at the bottom of the door.
- The Front Panel must be secured to the body in a way that the tension does not compromise its shape or function.
- The action of tilting and closing the Front Door must be manageable for the people interacting with the CDC.

A hook-inspired system was initially tested, with the idea of making the tilting and interlocking go smoothly and prevent the components from moving, once the tilt had completed. However, it was quickly discovered that to make the two hooks meet would require one hook to be shorter (illustration 129), compromising the tension and stability between the parts, allowing the door to move. A fear was that if the process was to not end in tension, or the person performing the tilt would have trouble making the parts interlock, they would resort to a more aggressive approach to close the front door, putting the rubber gasket at risk of being damaged. A prototype of the interlocking, inspired by the existing Triarca Trilite, is therefore made (illustration 130 and 131) which tests the system as one continuous bent surface. The challenge becomes determining the dimensioning of the interlocking parts and the angle of where tension is created, but interaction stays smooth.

To truly understand the relationship between angles of the interlocking and the interaction, prototypes of the relevant components must be built in materials with similar characteristics to the metal of the CDC. A verification process has been planned to take place after hand-in.

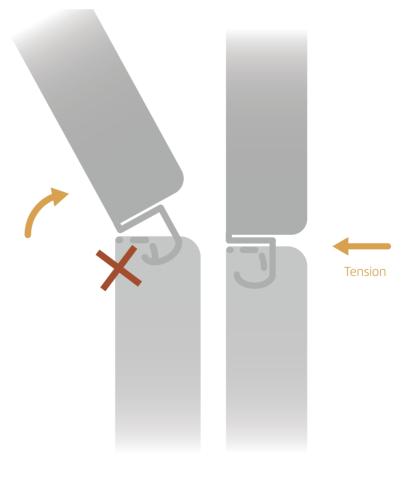


Illustration 128 Illustration 129

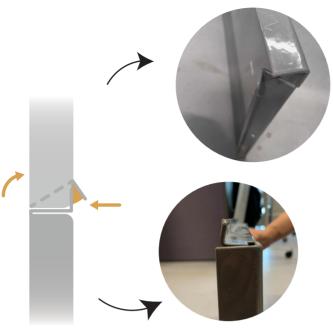


Illustration 130

Triarca Trilite: Angles unknown. The two sides do not meet; therefore no tension is felt when testing on the cabinet.

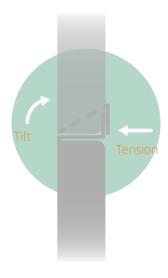
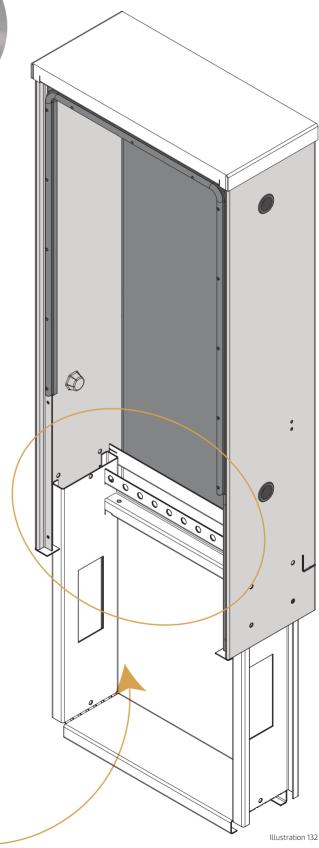


Illustration 131

Hypothesis: Angles 45/45, two sides meet! How much tension? How is interaction? How long would the sides be to create good tension?

To simplify the design and remove the complexity of creating an airtight seal between three components: door, panel, base it was decided to only have the cabinet airtight from the door and upwards since the panel primarily was underground anyway. To achieve this the gasket is changed to being at the bottom of the door and closed at the ends preventing dirt or small animals from entering. Furthermore, this also reduces the cost related to sealing the cabinet overall creating a win-win situation. The placement of the rubber gasket is shown in illustration 132.



# DEFINING THE INTERIOR DESIGN

When defining the interior of the design, it was decided to base the busbar system on that of Triarca's Trilite cable cabinet ('Exploring the Solution Space' - 'Deconstruction of a CDC'). When exploring how to install the busbar system (see illustration 133), a few issues need to be addressed since the concept differs from that of the Trilite cabinet today.

It was observed during the initial user visit ('Exploringt the Solution Space' 'The Electrical Fitter') that when the distribution companies receive a cabinet, the busbar system is already installed. During the deconstruction of the cabinets, the team learned that the busbar system is assembled and then inserted from the top before a lid is attached (app. 15 & 16). Due to the decision of fixing the lid to the base before getting it powder coated, it is no longer an option to install the interior from the top (see illustration 134). Should the interior be installed beforehand, the busbars and covers would be coated and it would no longer be useful, as the system's function is to be conductive to transfer power. On the other hand, if the lid and base are coated separately the air gaps in-between will no longer be filled.

When exploring if it was feasible to install the interior from the front, that was quickly debunked. Because of the flanges on the edges of the cabinet, it would be difficult to maneuver the components into place with the current design (see illustration 135). The most likely idea would be to make the door as wide as the busbar system thus creating a lot of unutilized dead space on the sides.

This left the installation of the system from beneath as the only option. To keep the installation method for the manufacture as simple as possible, it was decided to keep the components that the busbar rest on today (see illustration 136). This led to a redesign of the top metal brace creating a gap for the interior to slide into and then being put downwards into place before securing it with a bolt showcased on illustration 137.



Illustration 133



Illustration 134



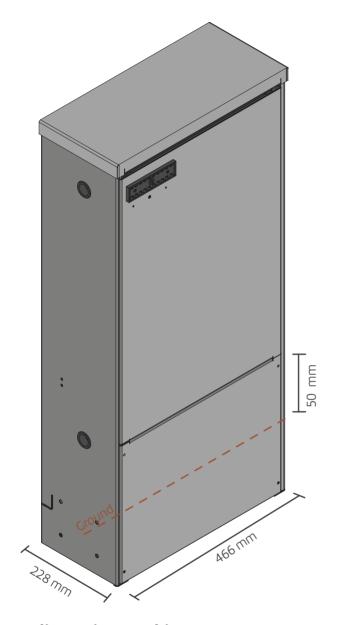
Illustration 135

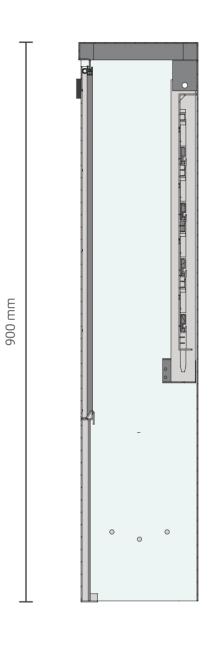


Illustration 136



Illustration 137





#### To dimension a cabinet

Illustration 138

After deciding on the sealing, attachment of the door and panel alongside the interior the outer dimensions of the cabinet above ground could be made. Due to the busbar system and the space, it needs alongside the parts that attach it, the width of the cabinet was set to **466 mm** (illustration 138). By adding flanges to the cabinet alongside a gasket the workspace is reduced for the electricians and electrical fitters. To compensate for this change, the depth of the cabinet has been increased to the maximum of **280 mm** (illustration 138). A dimension dictated by the requirements set by Nexel' ('A New Take on Cabinets' – 'A Competition) when choosing new cabinets. For the cabinet's height, a maximum of **900 mm** above ground was dictated by the requirements from chapter 3. To ensure that the fitters can easily open them without the door intersecting with the ground the panel is placed **50 mm** above ground. To further ensure the safety of the cabinet the busbar system is placed as far as possible away from ground level thus leading to a maximum cabinet height of 900 mm.

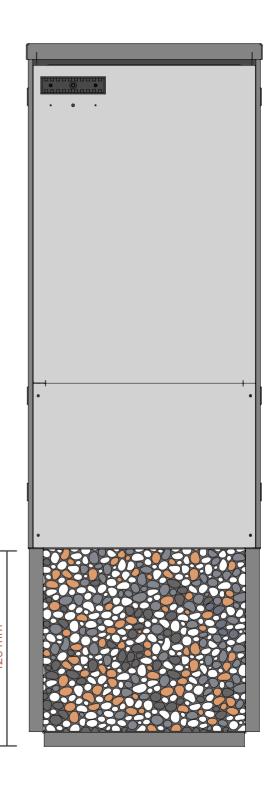
On illustration 138 the outer dimensions of the product proposal above ground can be seen. The maximum dimensions allowed are utilized to ensure easy interaction and the security of the electronics. The tradeoffs mean a heavier and more expensive cabinet. Something that must be evaluated upon when a finalized design is achieved.

# ADDRESSING THE BUOYANCY

When developing an airtight concept, buoyance has been a concern since choosing the direction. Even though when mentioning buoyance to the electrical fitters in chapter 3 ('Feedback - An Experts' Opinion'), they were convinced that the cabinet wouldn't move if the cables are secured. When exploring the different cable attachments methods in chapter 3 ('A Combinatorial Design Approach') cable binders were one of the options considered. It is a quick and effective way of attaching a cable and is always carried around by the users. To maintain the simple workflow, it was therefore decided to maintain the bar that is used today.

During the interview with both N1 and Trefor's electrical fitters (app. 11 and 12), it was discovered that for stability purposes, part of the plinth gets covered in gravel, something that could be utilized as counterweight for the cabinet. When calculating the buoyancy (app. 25) the result showcased a force of 110 kg lifting the cabinet. Assuming that each of the four sub cables from the two supply cables pulls by an equal force, this would mean a downwards pull of 13,75 kg on each. To decrease this force the plinth was therefore made as long as possible. When visiting the electric fitters (app. 11 and 12) it was observed that the Triarca cabinet arrived with the plinth pushed into the cabinet. A design feature that would be ideal to replicate to minimize transportation and packaging cost. As seen on illustration 139 this allows for a plinth that is 450 mm whereof 420 mm can be filled with gravel as counterweight.

The result shows that this amount of gravel only contributes approximately 44 kg of counterweight, leaving a remaining 66 kg of buoyancy. When calculating the force each cable would be exposed to, the calculation assumed the remaining 66 kg would be equally spread amongst the eight distributions cable leaving a force of 8 kg meaning the gravel effectively reduced stress by 42%. A test with the ABB Combi-Line cabinet fuses was conducted to verify that the cables could withstand the force no problem (app. 26). With the results validating the assumption no further investigation of counterweight was done.



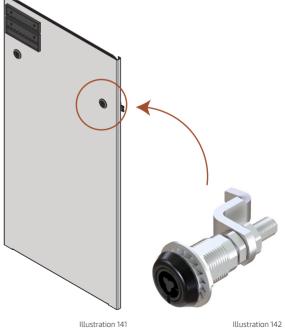
# **HOW DO WE CLOSE THE CABINET?**

When exploring how to attach the front cover as well as the panel it was discussed whether both components need the same solution. Looking at the panel, the most essential part of the attachment is to secure it prober so it can act as edge for the front door to latch upon. The discoveries from the different use scenarios ('A New Take on Cabinets' - 'Feedback -An Experts Opinion') showed that this interaction is not necessarily done every time and a simple screw solution were opted in to (illustration 110-114). It was considered using bolts with a triangle head but since the panel was underground level this seemed like an unnecessary cost increase which would also complicate the workflow. Locking the front door proves a bit more difficult to solve. The requirement states that the interface must be with a triangled interaction method and combined with the requirement of the product proposal being airtight, this narrows the solutions space significantly to either triangled bolts as seen on the ABB Combi-Line cabinet or triangled locks such as rotary locks or compression locks. When exploring the solution space, one of the first iterations was to lock the front door with triangled bolts. But during feedback, it became apparent that securing an equal pressure around the seal would be difficult with creating a specific sequence like seen on car tires (illustration 97), ultimately disrupting the users' workflow. An alternative solution was to remove the front lock from the outside and make it a sliding lock mechanism on the inside (illustration 140) ('A New Take on A Cabinets' - 'Prototyping 1.0'). However, due to the design of the flanges holding the gasket this and a fixed lid the access became impossible thus dismissing the idea. To compress the gasket sufficiently, a lock that pressed the door and base together was needed and compression locks with a triangular interface were explored. On illustration 142, a latching solution is shown. Turning the lock consists of a 180-degree rotation. The first 90 degrees move the cam from vertical to horizontal while the second 90 degrees pulls the cam towards the base compressing the seal and creating a tight seal. Two maintain an equal pressure when a lock is placed on both sides (illustration 141), meaning the users only need to interact in two places to fixate the door thus disrupting the workflow minimally while maintaining a familiar interface. To validate these assumptions models were made of three ideas and a simulated scenario were conducted making it apparent that the compression latches changed the workflow the least. The compression lock chosen is the Southco E3-13-17 (Southco, 2024) with a clockwise 90 degree turn and its counterpart E3.223-17 (Southco, 2024) with counterclockwise rotation. Both locks have a maximum compression force of 450N (app. 27). Illustration 141 shows the current design of the door. To create stability the edges are bent slightly inwards. An initial concern was that if the edge were to be extended until it connected with the base then scratching could occur damaging the coating or gasket. The next step for the door and gasket design is to calculate whether the compression lock creates too much pressure, thus damaging the gasket.

"We open and close the door multiple times, and with a lot of screws, it would take too long and be annoying." - Mathias Kodahl Jensen, Electrical Fitter



Illustration 140



# WHAT ABOUT CONDENSATION?

Condensation can be perceived as the enemy of most electronics, especially within the CDC, as exposure to water creates a risk of corrosion of components and short-circuits to any electrical system. On a summer day, the aluminum cabinet absorbs heat from the sun. Combined with the heat-generating electronics within, the temperature of its insides can be expected to rise fast. Air that is heated can absorb and hold onto water, in the shape of water vapor (NASA, n.d). Once the temperature drops, or encounters a cooler surface, the water vapor is released, becoming the condensation we all know, either from the walls of our bathroom after a long, hot shower or enjoying a cold, canned beverage on a hot day (illustration 143). This was also observed to be the case during the rapid prototype tests ('A New Take on Cabinets' – 'Prototyping 1.0'). The following section describes how this issue is solved for the product proposal.



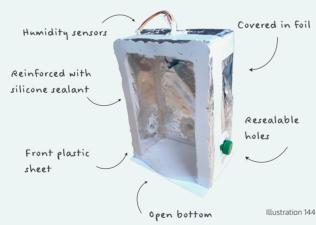
Illustration 143

#### Validating the test

To tackle the problem of condensation an experiment was set up where holes were added to the design of an airtight chamber. The hypothesis is that the water will only rise to the hole's top point when submerged in water. This was tested and validated with small scale 3D printed models (app. 28). Creating holes in an airtight chamber might seem counterintuitive to its purpose, but if placed strategically, the idea is that they can help reduce condensation in the cabinet without compromising the ability to negate the effects of flooding.

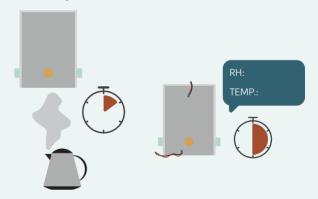
#### **Testing setup**

To validate possible features of the product proposal with the ability to negate the threat of internal condensation occurring, a test setup is created.



#### The setup

The test is conducted in three setups: Without holes, with one hole on the back and lastly, a test with two holes on each side of a box. The goal is to test the effectiveness of the holes for A) reducing moisture inside the cabinet B) reducing the temperature inside the cabinet. In addition, the box will be held above water for 10 seconds and left alone for 30 minutes while the sensors record the temperature and RH values every 10 seconds.



#### Understanding the terms

Illustration 145

Working with condensation, and testing for ways to prevent it, three terms deserve clarification to simplify the process of understanding of their connection.



Temperature (Celsius) can be perceived as a container, changing its capacity and size depending on its value, The Temperature Bucket is created. All other values are relative to this.



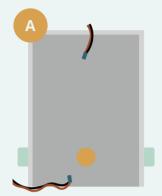
Relative Humidity (RH) (Percentage) describes how full of water vapor The Temperature Bucket has become. As the imaginary container changes in size, so does the required volume of water vapor for it to reach 100%.

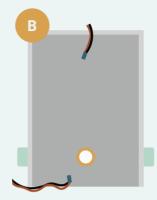


Illustration 148

Once the RH reaches 100% The Temperature Bucket is full. The dew point (celcius) describes the point where the bucket overflows, if the temperature drops but the vapor remains. The air releases vapor as water on nearby surfaces, causing condensation.

#### The results





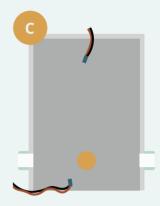


Illustration 149

This setup shows that there is a RH of 95 % (the cap of the sensor) at both ends of the box. The imaginary bucket of the top and the bottom remains full throughout the test as temperature drops, because there is no way for the humid air to escape.

In this setup a decrease in RH in the bottom half due to its means of escaping through the hole. It stays high in the top, as humid air tends to rise upwards. If given more time, it is assumed that there would be a decrease in RH in the top half, once the air was able to transport the humidity to the bottom and out through the hole.

In this setup, a decrease in RH is also detected in the bottom half as well as a high RH at the top like in the 2nd setup. While the RH went down in the bottom half, along with the temperature, it seemed as if the solution worked well. However, during this discovery, it was noticed that the RH of the top was on the rise, raising speculation that the vapor simply rose to the higher, warmer part of the box, instead of escaping through the two holes. When the imaginary bucket of the top was full, the RH value of the bottom half seemed to steadily decrease, thanks to the holes.

## **Takeaways**

(see app. 29 for full results and data results).

As the temperature differs from the top half of the cabinet to the bottom half, a problem occurs. It is known that hot and humid air rises. If the bottom half of the cabinet is significantly cooler, this part will have trouble in absorbing the vapor and escorting it out of the cabinet. As observed in the third setup, causing a greater divide between the RH values as temperature falls.

When reviewing the results a few conclusions can be made: (1) The third setup shows that the temperature decreases rapidly in the bottom of the box compared to the top where it actually maintains temperature for longer. This causes only the imaginary bucket in the bottom of the box to decrease in size. This means that the water vapor no longer can stay in the bucket and needs somewhere else to stay, causing it to rise to the top, thus increasing the RH as well. For the product proposal, this means that there will be a major risk of condensation occurring at the top of the cabinet if two ventilation holes are placed respectively to the 2nd setup. It was therefore decided to have one hole for ventilation only since the results indicate a slower-paced and uniform cooling,

minimizing the risk of condensation. In addition, (2) for safety purposes, it was decided that a foam cutout was to be placed on the roof on the inside of the cabinet, to absorb and hold the water vapor until the air is able to absorb it.

The diameter of the holes tested were of Ø 20 mm. A hole this size would allow for foreign objects and small animals to enter the cabinet thus risking the integrity of the solution. From the interview with the Electrical Fitters (App. 11), snails entering the cabinet is an issue due to their slime beings conductive. To prevent this from happening with the ventilation holes, multiple holes are made with the diameter of 10mm. The holes are placed above ground but below the edge of the door to ensure an airtight chamber is maintained. It would be beneficial to conduct more tests to measure the effectiveness of the holes over a longer period to conclude the most effective configuration. These tests will conclude on:

- The ability of the configuration to reduce RH in the
- The ability of the configurations to reduce temperature in the bottom.

# **NEREUS AT46**

Nereus (illustration 160) is a reinterpretation of the traditional cable distribution cabinet. Thanks to its EPDM rubber gasket an airtight chamber is created, sealing the door along the edges. A chamber which ensures that the flooding problem experienced today won't affect Nereus. It has maintained key features such as a mounting bar for the cables (1), a name and ID tag for the distribution company (2), a locking mechanism utilizing a triangular interface (3) and a brace for stability (4).

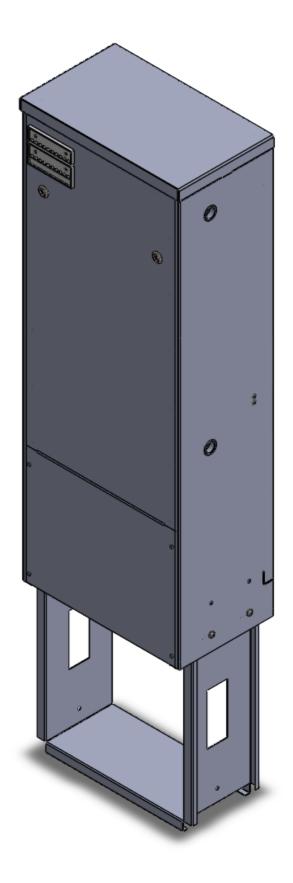
### The name identification tag

For the name and ID tag the height dimensions of the Triarca cabinet were chosen. This ensures that the ID can be moved and eliminates the need for additional components. Requirement ('Must be able to attach 10 characters in the ID holder') dictates that it must be possible to attach 10 letters to the cabinet. During the first user visit ('Exploring the Solution Space' – The Electrical Fitter) it was observed that the current cabinets facilitated 7 letters. Therefore, a new size is designed with the capability of 10 letters.

## The stability brace

When moving the base of the aluminum cabinet after removing all other components ('Exploring the Solution Space' – 'Deconstruing of a CDC') it was observed that a clear lack of stability was present hence the addition of a stability brace. It is therefore assumed that the design of Nereus will experience the same challenges and a brace is also added here. It is strategically placed in the back, so it won't intersect with the plinth when moving it upwards. The goal of the Nereus cable cabinet is to ensure a reliable power supply during flooding so agency can be preserved for the end-user while also decreasing risks for the distribution companies.

With an initial model of the Nereus cabinet and a basic understanding of the relationship between components the concept can now be tested. The next chapter will work towards achieving a proof-of-concept (Gillis,2023) before transitioning to a proof-of-business-case.



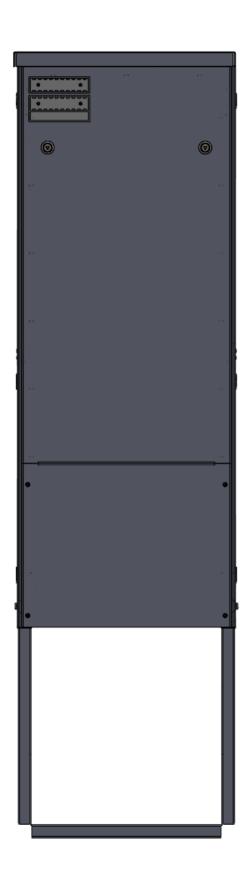




Illustration 150

# CHAPTER OS DETAILING FINALIZING THE CABINET

# **SUMMARY**

This chapter presents the finalization of Nereus design. Through protoyping, tests and feedback from a production company adjustment are done, while simulation is performed to confirm the cabinet creates an airtight chamber. This leads to the presentation of material choice, production methods and assembly. The chapter concludes with product specifications.

- 5.2 Choosing the Materials
- 5.3 How to look like an upgrade?
- 5.4 Interactions & Scenarios
- 5.5 The Last Details
- 5.6 Production
- 5.7 How is Nereus Assembled?
- 5.8 Production Specifications

# CHOOSING THE MATERIALS

Earlier on in the process it was decided that Nereus should be made from a metal ('Proving the Concept' - 'Problem Slicing') in order to use metal bending for production. During the market analysis ('Exploring the Solution Space' - 'Market Analysis') it was noted that the cabinets coated with Rilsan was produced in either aluminum, stainless steel or galvanized steel. For stainless steel the alloy 304 were chosen since it is the most used and versatile material while being corrosion resistant and having excellent bending properties (MetalTek, 2024). The Aluminum alloy 5052 were chosen due to the same properties being present (Kliecker Metal Corporation, 2020).

On table 1 a comparison of different properties can be seen (MakeltFron, 2024) (Unifiedalloys,2024) (Crossroad Galcanizering, 2020). These properties are chosen based on discussion throughout regarding production, use and cost.

Even though the stainless steel has better corrosion resistance and is stronger aluminum is chosen to be the primary material for Nerues. Because the product gets coated, those properties are not as important. Instead, weight is of major importance for the fitters, discovered during the initial interviews. When analysing the CAD file (illustration 151) the volume can be found as 0.0052m3. This would mean a cabinet of SS304, Alu5052 and galvanized steel would weight approximately 42 kg, 14 kg and 41 kg respectivly. Based on this aluminum 5052 is chosen as the material for Nereus.

	Stainles Steel 304	Aluminum 5052	Galvanized Steel
Density (g/cm3)	8,00	2,68	7,86
Corrosion resistance	Low	Medium	Medium
Tensile strength (MPa)	505	290	565
Extrusion		Yes	Yes
Stamping	Yes	Yes	Yes
Lasercut	Yes	Yes	Yes
Deep drawing	Yes	Yes	Yes
Can be rilsan coated	Yes	Yes	Yes
Price	Medium -high	Medium	Low

Table 1

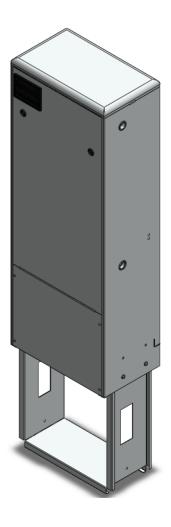


Illustration 151

# **HOW TO LOOK LIKE AN UPGRADE?**

Throughout the report the design of the CDC has been developed based on a form-follows-function approach. During the different ideation processes the more radical solutions have been dismissed due to the narrow solution-space (Dorst & Cross, 2001) dictated by the technical requirements. The functional aspect has overall dominated the design process. From this point, a pursuit of intentional aesthetic development began, looking for minor opportunities to move within the boundaries of the solution-space while respecting the established and function-driven aspects of the CDC.

#### GoPRO - A case study

For Nereus to be visually identified as a waterproof upgrade a case study of GoPRO cameras is conducted. GoPRO is a product line of small, action cameras, meant to be brought along by the user on their adventures. Looking at the evolution of the camera and its features (illustration 152) the story of the waterproof feature can be seen. Initially, an add-on solution that allowed the user to opt into a new use scenario was designed. Over time this feature became integrated into the design language of the GoPRO camera ultimately enhancing the credibility of the waterproof feature, which can be adapted into the development of Nereus aesthetics. Appendix 30 shows a comprehensive analysis of the different GoPRO cameras.

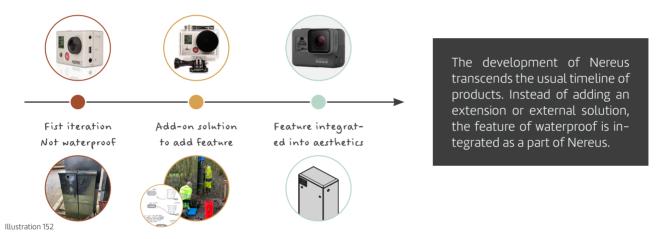
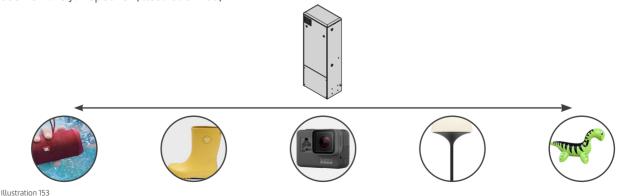


Illustration 152 shows a range of waterproof products with different aesthetics. On one side, products that belong in water, both in function and aesthetically like pool toys and boats. On the other side are waterproof products where the initial aesthetics are crucial for their identity and thus the waterproof feature becomes a hidden integrated feature like seen on the JBL speaker (illustration 153).



When comparing Nereus with the other products on illustration 153, it can be placed in between the neutral and hidden design expression. The cabinet must be invisible in the urban space ('Exploring the Solution Space' – 'The City Architects') and thus not visibly disrupt which the products that explicit communicate waterproof would do. The products placed here are identified with fillets and only minor visible air gaps and an overall smooth and flush surface.

# **PROTOTYPING 2.0**

Before reaching a finalized product proposal, the aesthetics of the lid will first be addressed based on the findings of the GoPRO case study. Afterwards the final touches in relation to interaction with the door and panel will be conducted simultaneously with simulation of the gasket's compression behaviour.

#### The Air gap

The conclusion from the case study was that the air gap between door/panel and base were crucial to signal water-proof while also allowing for space to mount the door. Three versions (illustration 154-157) were therefore modelled of the current lid with different airgaps.









Illustration 154

lustration 155

Illustration 15

Illustration 157

When evaluating the three air gaps of 1mm, 2 mm and 5 mm it became apparent, that a 5 mm air gap would expose the gasket too much and was quickly dismissed as being too large. In addition, when building a mock-up in cardboard and testing how to close the door, it became apparent, that it was difficult to centre the door when closing the door. This resulted in the user having to scrape

along the joint between the door and the panel, leading to the conclusion, that the joint would be damaged in the future. When testing the interactions for 1 mm and 2 mm no significant difference (Illustration 157) was present and the 1mm gap was therefore chosen so centralizing the door was easier.

# Rounding of the lid

On illustration 158–160 three different variants of a new lid can be seen. This lid is designed to be flush on all four sides with the base creating a more uniform and integrated look mimicking the reference products from the case study. A fillet of 20 mm, 10 mm and 3 mm were applied to the design. These were shown to Per Sørensen from Trefor during a team's meeting (app. 31). This interview provided little valuable insights into the different shapes since it was too hard to determine from the initial renderings. Instead, the team decided to round of the edge as much as possible to limit the surface area where posters, stickers and graffiti could be applied.







Illustration 158

Illustration 159

Illustration 160

#### Changing the panel

When testing the carboard mock-ups of the panel, it was found to be difficult placing the panel correctly because of the fitter essentially having to balance the panel while placing the bolts (shown on illustration 163). A new approach was taken to improve the design, to ensure that the fitters placed the panel correctly by adding two feet at the bottom of the base. Furthermore, this enhances the panels' ability to create a secure edge for the door to attach to. The attachment was prototyped and tested with and without feet (app. 32) when it was moved to a location without a surface to rest on (illustration 161-162). This confirmed the difficulties present when trying to align the panel with the bottom and the feet were therefore added.



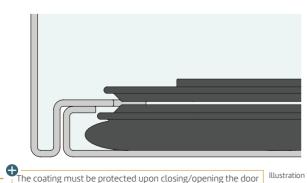




To further strengthen the attachment of the panel thread rivets (illustration 164) were inserted in the cut out previously made for the bolts. By doing so, the simplicity of the bolts were kept while enhancing the strength of the assembly.

## The change of the door

When testing the attachment of the door on prototypes (illustration 165) it was discovered that aligning the surface of the door and base completely flush was extremely difficult. Since nothing prevented the door from being over compressed a risk of damaging the gasket were present. A change was therefore made to the design giving the door an additional bend. This surface would face up against the surface of the flange on the base ensuring that the gasket is not capable of compression more than 40% (Elasto proxy, n.d), which is the recommended compression percentage for achieving ideal sealing. The last flange of the door, highlighted on illustration 166, also ensures that no sharp edges intersect between door and base thus damaging the coating.





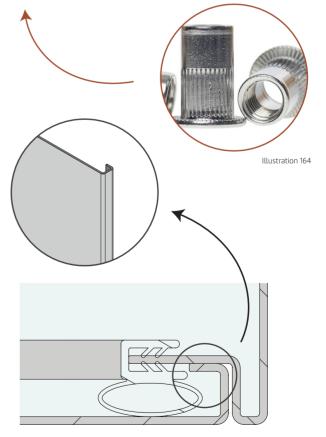


Illustration 166

#### Simulation and tests

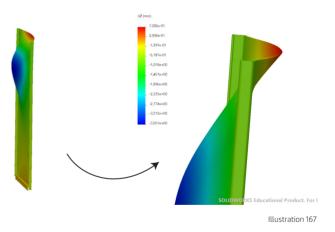
With the problem of over compressing the gasket solved, it needs to be tested whether the aluminum door applies enough pressure to achieve the 40% compression. A simulation of the door is therefore made to evaluate its deformation. The door is affected by two forces. The lock and the gasket. Since the gasket is made from cellular EPDM identifying a young's modulus is difficult without extensive testing. Obtaining the correct data would therefore only be possible, if given the datasheet specifically for this product. To be able to test the compression of the gasket, a smaller test was therefore conducted by the team. Here the force needed to compress a gasket of

6 different lengths were tested (app. 33). The hypothesis was, that the force would increase as a result of an increase in length thus providing a theoretical tool for calculating the force of the full gasket. The force required to achieve the 40% compression percentage, which is equivalent of 6,4 mm deformation. While elastomers like EPDM are not known to follow Hooke's Law, this test will be considering the gasket to be a spring, for simplification of calculation. Hooke's Law is be applied to determine the ability of a spring to compress.

The six tests show that the value k can be considered to scale in a linear fashion per centimeter of gasket. This means that the Force(N) can be calculated, using the k for 200cm of gasket, as well as the ideal compression of 6,4 mm. The result shows (app. 33) that the gasket needs to be uniformly applied 35kg (358N) of pressure to reach the desired compression. As it is compressed, the gasket pushes back at the door. To create the desired uniform pressure across the gasket, the door may not deform outwards. By doing so the compression percentage will fall lowering effectiveness of the seal. A general rule of thumb is, that a gasket should not be compressed with no less that 15% which is equivalent of 2.4mm. To calculate whether or not the door deforms with more than 2.4 mm the pressure from the gasket needs to be calculated. This can be done through the formular: P = F/A

Where F is the force of the gasket and A is the contact area it has with the door. When doing this (see app. 33 for calculations) we get a pressure of 21.500 Pa or 21.5 Kpa. With this information, and the maximum force for the lock known as 450N ('Proving the concept' - 'How do we close the cabinet') a simulation can set up.

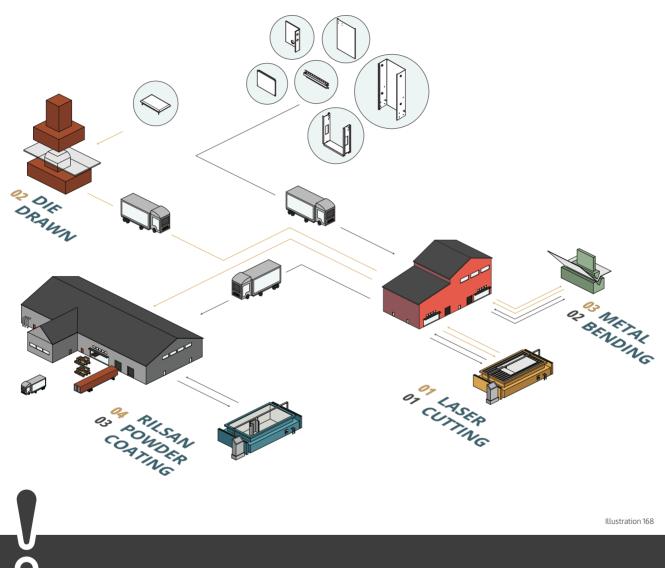
 $F = k \cdot \Delta L$  F = Force in Newton k = Spring Constant in N/m  $\Delta L = Deformation$  of length in Meters



When plotting in the data the following model is shown (illustration 167). On this model two things happen. A deformation at the top of 0.7mm happens while a deformation of 3.6mm happens in the in the centre. The centre deformation would however not appear in real life. This is due to the compression locks being applied as a force in the simulation and not a reactive force or constraint which they would be in real life. This is done to simplify the model. More interestingly, in the top of the model it can be observed that an outwards deformation of only 0.7mm deformation happens. This correspondents with a reduction in compression on the gasket with 4.5% leaving the total at 35.5% and well above the 15% minimum requirement. From a theoretical viewpoint the two compression locks should as such be enough to keep the door in place while compressing the gasket, however, further tests need to be conducted on a 1:1 model with accurate dimensions and correct materials alongside a piece of the gasket from AAG to validate this.

# THE PRODUCTION OF NEREUS AT46

Illustration 168 showcases how Nereus is manufactured. For simplicity, the illustration will leave out all the standard components. It was decided that the following components: the base, plinth, panel, door, busbar holders and the feet will use the same production methods. The productions steps for these components follow the black guideline and numbers on the illustration. Different from the rest is the production of the lid. This is due to the desire of double rounded edges and can only be achieved by deep drawing. The production of the lid will follow orange guideline and numbers.



# **Deep Drawing**

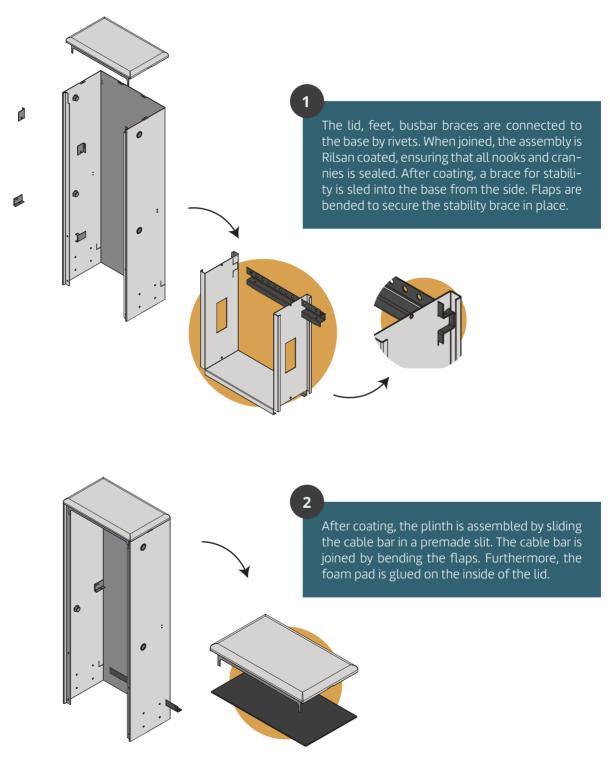
The production method chosen for Nereus lid is deep drawing due to the curvature. The process is transforming a flat sheet metal by 'punching' the sheet into a hollow die. In addition, the hollow die combined with the mechanical action of 'punching' applies both tensile and compression forces that transforms the shape under hight pressure. (ATACO, 2024)

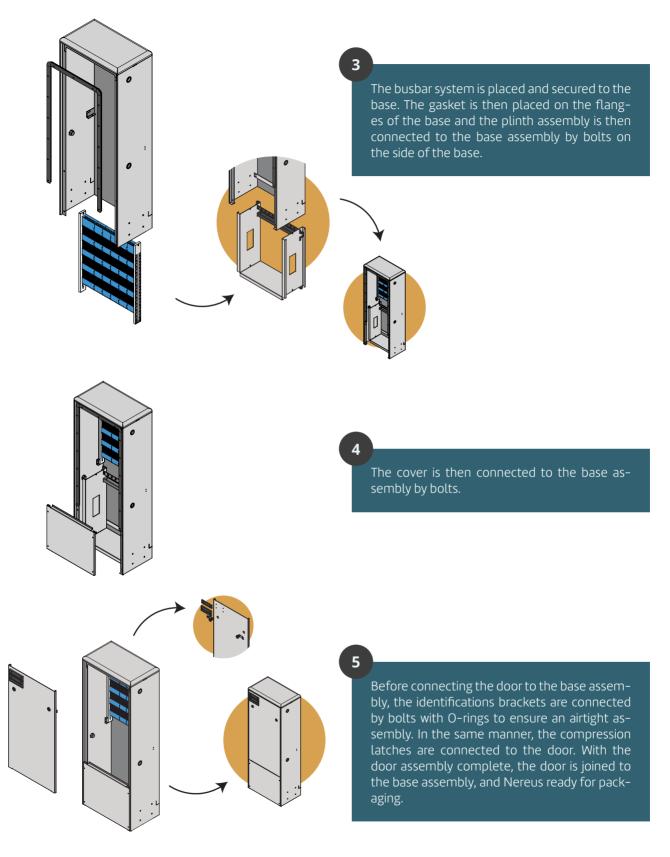
# **Powder Coating**

Rilsan is primarily applied by two different methods: electrostatic spray coating and fluidized bed dip-coating. In this case Nereus is 'fluidized bed dip coated' to ensure that all gaps are sealed properly. The process consists of immersing a preheated element into powder suspended by rising airflow. When the coating comes into contact with the element, it melts and forms a film on the surface of the component. (Arkema, 2022b;2022c)

# **HOW IS NEREUS ASSEMBLED?**

With an overview of how Nereus is produced, assembly details for the manufacture are specified. Nereus is assembled by using bolts, washers, rivets, waterproof bolts, nuts and O-rings in addition to standard components, listed along the way. The follow section will describe and illustrate (169) how Nereus is assembled in the correct order.





# **PRODUCT SPECIFICATIONS**

# Functionality

- The proposal must be able to withstand future, more severe flooding incidents p. 14
- The surface must not be conductive p. 24
- The product proposal must not corrode
  - The product proposal must be resistant to salt p. 25
  - The product proposal must be resistant to all types of water p. 28
- The product proposal must fit into the existing infrastructure of the power grid p. 28
  - The product proposal must be integrated or invisible in the urban space p. 42
  - The cabinet must be able to be coloured based on the RAL system. p.68
- Maximum weight 40 kg
   p. 68
- Maximum height above ground: 900mm p. 68
- Maximum depth: 280 mm p. 68
- The cabinet must be designed to prevent condensation around the interior p. 68
- The proposal Must have identification of class II insulation p. 68
- Must not exceed 70 cm below ground p. 64
- The ID must be transferable from the old design p. 40
- Cable must be fixed next to each other p. 66
- Must be able to attach 10 characters in the ID holder. p. 68
- The busbars must be fixed into place p. 40
- It must be possible to remove the entire front face p. 41
- Must have a triangle interface lock p. 49
- MUST BE FLUSH
   p. 75
- The gasket must not be at risk of being damaged when closing the door p. 76
- The coating must be protected upon closing/opening the door p. 91



- The cabinet should be coated with anti graffiti. p. 68
- The product proposal must be applicable in all contexts p. 22
- The proposal must function without needing permission in the build-up phase off an incident p. 28
- The product proposal must not encourage vandalism through its shape or surface p. 40
- The product proposal must not resemble other types of street furniture p. 43



- The solution must be labelled
  - Manufactures name or trademark
  - Type designation or identification number or any other means of identification
  - Means of identifying data of manufacture
  - Rated current of the assembly
  - Rated voltage of the assembly
  - Rated frequency of the assembly
  - IEC 61439-X (X shall be defined)
- The ambient air temperature must not exceed +40 degrees (average over a period of 24h does not exceed 35 degrees. And under -25 degrees.



- Must be able to operate in the temperature interval
   -25 to 40 degrees Celsius
- Must be able to operate in 100% humidity in -temperature interval -25 to 27 degrees Celsius
- Must have an IK code of 10
- Must have an IP code of 34D+
- Must have a lock that prevents the public from accessing the interior
- Must be UV resistant in temperate climates
- The cables must be easily connected through the front
- Cables must enter the cabinet from below

# CHAPTER OBUSINESS MARKET IMPLEMENTATION

# **SUMMARY**

The last chapter presents Nereus from a business and market perspective. The market size is investigated before presenting a revenue stream and sales price. The strategic fit (Louise & Haase, 2022) for Nereus is then presented focusing particularly on product–market and product–user fit. Lastly the future for the project is presented in the form of a market implementation and future variants.

- 6.2 The Value Chain
- 6.3 Estimating the Cost
- 6.4 Strategic Fit
- 6.5 Designing a Product Series
- 6.6 Implementation Plan

# **ESTIMATING THE COST**

With production and materials established alongside a fully detailed design, the cost of Nereus can be established. Before setting a price for the product, the size of the existing market is investigated to determine what a realistic price could be

#### The market size

In chapter 3 it was established that the Danish market consists of 1.1 million cable distribution cabinets with a sale of approximately 21.000 new cabinets a year. Since it was observed that Trilite P21 XL were used for both N1 and Trefor, its price of 5750 DKK excl. VAT were used as a basis for the establishment of a market size.

If all cabinets in Denmark were to be replaced this would lead to a potential market of 6.325 billion DKK. However, not all cabinets are in zone where it would make sense to place a floodproof cabinet. Research shows, that 1/6 households in Denmark is considered in risk of flooding (illustration 171) leading to a market share of 1.035 billion DKK (Stephensen, 2024). This means that Nereus could take 16.6% of the Danish cabinet market for distribution companies given no other manufactures adapt floodproof solutions.

#### Revenue stream

Today the manufactures of cable distribution cabinets earn their money through tenders which provide them with supply contracts for a number of years. This business model, however, does not make sense for Nereus. Since the CDC solves a specific problem, the companies will buy directly from Nereus depending on their needs.

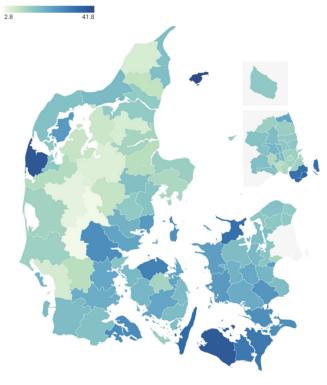


Illustration 171

#### Cost scenarios

To establish the cost of Nereus it is important to understand the expenses related to cabinets today. Two scenarios (app. 34) have therefore been set-up where different factors influence the TCO (total cost of ownership) for the distribution companies. These scenarios show how high the TCO can be when having to swap the cabinet prematurely during its 50-year lifespan while also during regular check-ups adding extra salary expenses.

Scenario 1 - Replacing a cabinet (no extra check-ups during the 50 years)

Cabinet cost: 5750 x2 Salary during installation: 3000x2DKK

Total cost: 17500 DKK

Scenario 2 – Changing the cabinet once prematurely (3 additional check due to flooding)

> Cabinet cost: 5750 x2 Salary during installation 3000x2 Salary during check-ups: 1800x3

Total cost: 22,900 DKK

#### **Evaluation**

When looking at the scenarios it becomes apparent that even with one premature change the TCO for a cabinet on a location increases drastically as a result of flooding. Even though the calculations are a rough approximation, they can still be used to show how expensive a regular cabinet is to maintain even though their cheap initial cost. Furthermore, a cabinet in a risk zone will always be exposed meaning that something will happen again until a solution is found, which today is buying an extension increasing TCO further.

#### **Proof of business case**

To validate the business case of Nereus an estimation of material, components and production cost is found. The basis for this cost estimate is that all production is outsourced thus reducing upfront investment. For simplicities sake, this estimate does not involve expenses related to salary, facilities, tools and transportation.

#### **KM Vandskæring**

To gain an accurate price estimate, contact was established with KM Vandskæring who performs bending, laser cutting and water jet cutting in Aalborg (app. 35). While discussing the project, feedback was given on the material choice, and a recommendation of swapping from aluminum 5052 to 5754. Furthermore, KM Vandskæring provided production feedback related to the bending lines and their placement (app. 35). This led to a finetuning of the dimensions related to the flanges. Looking at table 2 an overview of the different expenses can be seen. The production, coating and material cost has been calculated for each part (app. 36). For the deep drawing of the lid, a reference product was found since a reasonable price were not obtainable through research. The cost of this reference component is relatively low since upfront investment of die and machine is already covered. To accommodate for the expenses not taking into consideration a margin of an additional 100% is added to the cost of the product. This covers transportation, salary, administration etc. This number is likely way to high thus representing a worst-case scenario.

When talking with Kenneth from Stormflodssikring (app. 1) he said, that after experiencing damage people are more willing to buy, indicating that if a cabinet has been damaged at an exposed location, the distribution companies might be more willing to invest. Illustration 172 shows a map over a section of Aalborg. On it, the placement of CDCs can be seen alongside the blue spots present at a 10-year incident.

Cost Estimate	
Standard components	561,34 DKK
Coating	410,97DKK
Material	336,12DKK
Laser cut	538,38DKK
Bending	315,70DKK
Stamping (reference product)	3,44DKK
Transport	-
Salary	-
Tools	-
Facilities	-
Total	2.165,95DKK
Total cost including marign	4331,9 DKK

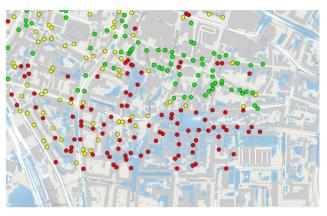


Illustration 172

This map shows how much it differs with a small area, whether a cabinet is exposed or not. As such, establishing the actual market size is difficult and would require a full cross reference of the cabinet's placement and a flooding map.

#### Red – high risk

• Cabinets should be replaced pre-emptively to prevent damage during flooding

#### Yellow - medium risk

 The replacement of cabinets is determined by a cost/risk assessment by the Distribution Company

#### Green – low risk

 Cabinets are not likely to be replaced at this time

Since the market is highly competitive and not a lot of information is available it is hard to determine the correct price without a thorough market investigation. When looking at scenario 1, the total cost of ownership is 17.500 DKK.To obtain a competitive advantage, the TCO for Nereus must be lower throughout its 50 years lifespan. Based on this value-driven pricing approach, a reduction of 20% is set. This number is an estimate of what point Nereus becomes competitive viable but cannot be known for sure. Overall, this sets the sales price of Nereus at 14.000 DKK.

## STRATEGIC FIT

To succefully implement Nereus as a new cable distribution cabinet it has throughout the project been a subconsius goal of ensuring a strong strategial fit (Haase & Laursen, 2022) (Ilustration 173). During the development phase different principle, concepts and models have been made trying to fullfill the product-user fit and product-market fit.

#### Product-Market fit

When looking at the product-market fit it was clear, since the cable cabinet direction were chosen, that the approach to the market fit was to gain a competitive advantage by differentiating in the market through the additonal feature of being floodproof. The design process were difficult since there was a desire to explore radical, innovative solutions for both design and technology (verganti, 2003) (illustration 173). However, in reality the market demanded incremental changes since new solutions have to fit into the grid. Instead, when looking at the 4P-model (Mabogunje et al., 2013), the radical innovation came on the paradigm parameter where the fundamental definition of a cabinet were challenged by making it an airtight chamber. Though difficult to asses at a conceptual stage the market-fit seems strong due to the differentitation in features driven by needs in a otherwise red ocean market.

#### Product-User fit

When looking at the product–user fit it can be seen from two perspectives: The fitters and the distribution companies. Nereus delivers a solution meeting the needs and expectations the fitters and electricians have. It deals with flooding and secures their flow of electricity. Nereus creates a saftey insurance for the companies reliefing them of an otherwise growing concern creating a strong user fit. For the fitters the product proposal aims to disrupt their currrent workflow as little as possible while maintaining the current features they value, however, to make a stronger user fit concrete feedback on a detailed prototype is needed to verfiy the findings and decisions made.

#### **Product-Company fit**

The focus throughout this project has been to make a strong product–market fit and product–user fit. However, when looking at the company fit it has been a priority to design a cabinet that reflects the values of the company. Nereus is an expensive cabinet that provides a saftey net with a lower TCO for the distribution companies and as such the company needs a brand of reliable and high–quality products. As a new company, the creation of a strong product–company fit heavely relies on the creation of branding and marketing.

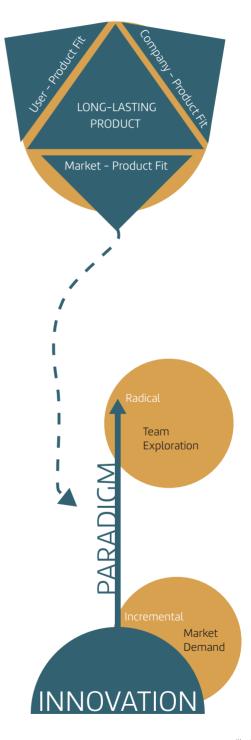
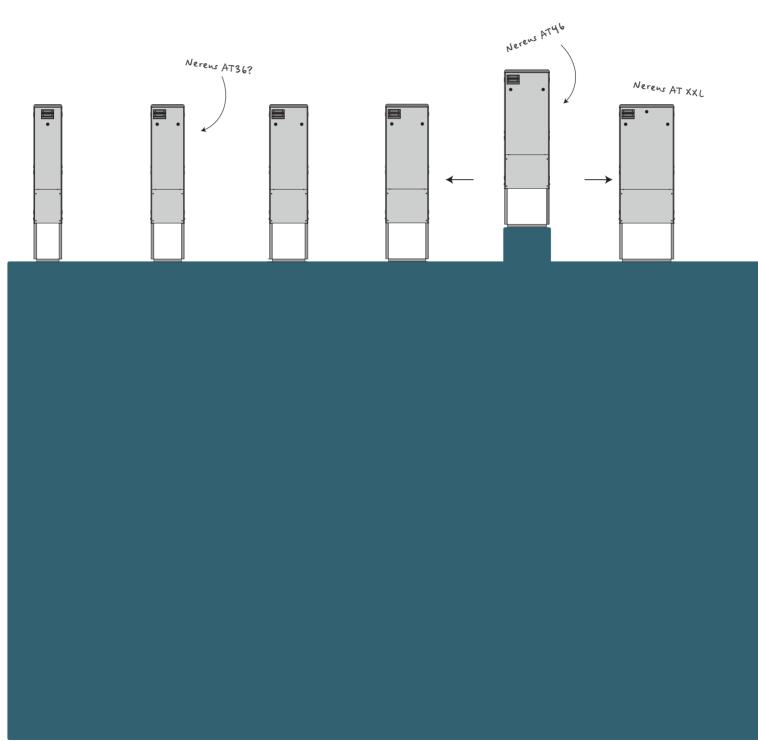


Illustration 173

# **DESIGNING A PRODUCT SERIES**

When looking at the market today a variety of cabinets exists ('Exploring the Solution Space' – 'Market Analysis'). Within each family different sized cabinets exists (app. 18) often indicated with different numbers such as Triarca Trilite P21 XL. The cabinet designed and presented is considered the first in a new series of airtight cabinets being the Nereus AT46. Illustration 174 shows an overview of the planned products within the AT-series for the future. The dimensions of these are dictated by the addition and removal of busbar modules.

Illustration 174



# IMPLEMENTATION PLAN

To map out the future of Nereus an implementation plan has been made. It is constituted of five phases that describes the next steps for the product proposal: 1) Product maturation 2) 0-series 3) Product Launch 4) Mass production & scaling 5) Establishing a portfolio. The implementation plan describes the steps needed to go from a single detailed product, Nereus AT46, to a company with a portfolio with different families and variants within.



# Step 1: Product Maturation

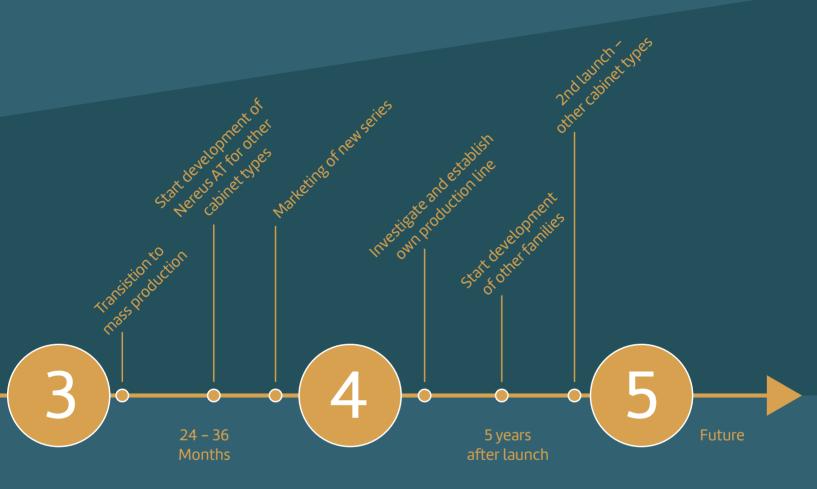
A product maturation process is initiated to finalize the design. 1:1 prototypes, with the correct material and coating are built so the interaction between door and panel can be verified alongside the sealing. Meanwhile the design of the Nereus AT-series is developed to accommodate for different contexts. A second proof-of-business-case is conducted to validate the proposal while also taking aspects such as transportation, distribution, facilities, tools and manpower into consideration.

# Step 2: 0-Series

Final agreements are established with different companies, so the supply of standard components and aluminum is ensured while also having dedicated manufactures for the cabinet. Different tests are performed on the finalized design to achieve necessary certifications for a CDC. In the meantime, sales channels are developed, and a 0-series is produced to help promote marketing and establish agreements with distribution companies.

# Step 3: Product Launch

The first batch of the Nereus AT product series is produced and launched in Denmark. In the aftermath of the launch proof-of-scale is investigated to determine the needs for a transition towards mass production. An investigation of other cabinet types such as TV, district heating and internet is conducted.



# Step 4: Mass Production Step 5: Establishing A Portfolio & Scaling

One year after launching the Nereus AT-series a transition towards mass production is initiated. A development phase is initiated to adapt Nereus AT into other cabinet types expanding the market for the product. The necessary certifications required is gathered and resources are relocated into marketing of the product.

Two-three years after launch an evaluation of the production line is initiated to check the feasibility of moving production internal to reduce expenses. The Nereus AT-series is relaunched with a focus on selling to different types of companies. To accommodate for the increased market, agreements with retailer(s) are made to sell the cabinet. With a reliable profit the development of additional product families is initiated with focus on other scenarios that require special made solutions such as areas with storms or artic temperatures while also analysing the global market to identify whether it is feasible to become an international company.

# **CHAPTER**

# **O7 EPILOG**WRAPPING UP (FOR NOW AT LEAST)

## CONCLUSION

While flooding in Denmark have been more severe these past years, the focus of the protecting the affected cities and its people from this natural disaster has increased. This master thesis project challenged the flooding problem. Instead of focusing on flooding prevention like the majority of solutions today, the focus for this thesis has been to provide agency for those affected, giving them the necessary resources to fend off against "invasive" water, by proposing a new cable distribution cabinet.

The process has culminated in the product proposal Nereus. The cable distribution cabinet is designed to withstand current and future, more severe, flooding incidents so providing a steady and reliable flow of electricity between distribution companies and their customers. Nereus is a reinterpretation of the traditional CDC incorporating a new key feature. With its open bottom, it does not prevent water from entering but instead utilizes the creation of an airtight chamber to safekeep the electrical components hidden inside. Nereus builds upon the established infrastructure of the power grid, by incorporating existing internal components, making the transition from current solution into Nereus easier to implement for the distribution companies.

Nereus provides the distribution companies with a cabinet that presents a unique feature that solves their ever-growing problem of flooding, thus giving it a competitive advantage over existing competitors. The product proposal challenges the business models of today, presenting a new strategy that doesn't rely on winning competitions, but appeals to the need for flood resistance solutions to ensure a reliant power supply for their customers.

Through its flood resistant design, Nereus acts as an insurance for the distribution companies in the eventuality of flooding, ensuring that the power supply is maintained. Meanwhile, it eliminates the risk of damage to the CDC thus lowering the total cost of ownership for a higher upfront investment.

With an aspiration to design a CDC capable of withstanding flooding Nereus has on a principal level achieved its goals. The success of Nereus lies within the unique value proposition and whether it can challenge an otherwise conservative market.

# REFLECTION

#### **Prototyping**

Nereus is a product proposal that falls into the category of solutions which are reliant on one feature to be implemented successfully. Therefore, having physically validated the product in a scenario akin to the real-world application is vital. However, a 1:1 prototype made with the correct materials and a rubber gasket is needed to do so. Due to the complexity of the design process and the scale of the product this was not attainable before handin, and an uncertainty exists regarding the effectiveness of the sealing. In retrospect, creating real size prototypes in the right materials could have proven to be beneficial to the exploration of more than one design challenge. As an example, the attachment between door and panel relies on the relationship between angles and the strain of material, which must be optimized to both ensure the correct amount of pressure for the gasket while creating a seamless interaction between CDC and fitter.

#### The design process

The development process of Nereus was for a long time primarily influenced by design thinking (Tollestrup & Laursen, 2017) approach, where the principles of co-evolution of problem-space and solution-space (Dorst & Cross, 2003) were explored. Due to the early introduction of Danish Standard and specific requirements the solution-space were limited which hindered the co-evolution process. When reflecting on the process this is especially apparent in the ideation processes, where too much time was spent trying to find the perfect solution. In retrospect, it is apparent, that when switching towards a more execution-based approach applying rapid prototyping (Schrage, 2006) while engaging in build-measure-learn (Ries, 2011) loops, the team kickstarted the otherwise stagnated design process. This would likely have led to a more tangible exploration of the solution space earlier. Furthermore, it could also have helped promote interaction and aesthetic aspects into the design process instead of being mainly driven by the functional aspect.

#### **Exploring the solution space**

This project worked with the problem of CDC's being compromised during flooding. An initial wicked problem of "how do we prevent the consequential damage of flooding" turned into a well-defined tame (Tollestrup & Laursen, 2017) problem of "how do we make a water-proof cabinet?"

The team's expectations were that when working with a tame problem, more time could be used on diverging during the design process. However, the fast limitation of the solution-space forced all non-incremental changes to be suffocated out of the project. As a consequence, the final proposal's aesthetics does not completely fulfill the aspirations set out, however, compared to products today it stands out as more integrated proposal when looking at the urban environment. The clearest example of this is the down-prioritization of working with anti-vandalism' due to distribution companies not evaluating upon this criterion. In retrospect there should be more diverging and exploration throughout the project.

#### A new business case

The CDC market in Denmark today is a very competitive space. Limited information was obtainable so there is an uncertainty of whether there is enough room for an additional competitor to enter the market, elaborating market analysis is therefore required to validate the feasibility of the business case. With a strategy that revolves around selling products depending on needs, and not submitting tenders for contracts, it seems plausible, given that the strength of the selling points is strong enough.

#### The design philosophy

Throughout the project, the process changed between a 'form-follows-function' and 'function-follow-form' approach. While form follows function acts as the usual philosophy for Industrial Design students, its opposite has been prevalent throughout certain aspects of the process. The narrow solution space established early forced the function-follows-form mindset onto the project. This can be seen in the case of creating a sealing method. Assuming from the beginning that the solution would resemble the current shape of a box, box-like sealings dominated the creative process. An effort was made in the beginning to challenge this idea, but it quickly faded due to the restriction of the form thus forcing the function to follow the form.



# LIST OF REFERENCES

#### Websites

Arkitektforeningen, 2024. *Stadsarkitekter*. [Online] Available at: https://arkitektforeningen.dk/vi-arbejder-for/arkitekturpolitik/stadsarkitekt/ Last accessed: 05-05-2024

ARKEMA, 2024. Wire & cable material solutions. [Online] Available at: https://hpp.arkema.com/en/markets-and-applications/wire-cable/wire-and-cable-material-solutions/#pa11 Last accessed: 19-05-2024

ATACO, 2024. Deep drawing: what is it exactly? [Online] Available at: https://www.atacosteel.com/deep-drawings-what-are-they-exactly/ Last accessed: 19-05-2024

Bjerre, k., 2017. En strømførende forklaring. [Online] Available at: https://fyens.dk/bolig-og-livsstil/en-stroemfoer-ende-forklaring Last accessed: 19-04-2024

Brittanica, 2024. *Permability*. [Online] Available at: https://www.britannica.com/science/permeability-physics Last accessed: 02-05-2024

Bryant, C., W., n.d. What's a diving bell? [Online] Available at: https://www.mapquest.com/travel/outdoor-activities/water-sports/diving-bell.htm Last accessed: 23-05-24

Bugosciga, 2021. *Hey Denmark! What's the little boxes?* I see them everywhere. [Online] Available at: https://www.reddit.com/r/Denmark/comments/psltw8/hey\_denmark\_whats\_these\_little\_boxes\_i\_see\_them/ Last accessed: 17-05-2024

Cablematic, u'n.d. *Black silicone case for camera lens GoPro Hero 2 ST42*. [Online Image] Available at: https://cablematic.com/en/products/black-silicone-case-for-camera-lens-gopro-hero-2-st42-HR028/ Last accessed: 23-05-24

Cambridge dictionary, n.d. *Permeability*. [Online] Available at: https://dictionary.cambridge.org/dictionary/english/permeability Last accessed: 02-05-2024

Cerius, n.d. Om elnettet. [Online] Available at: https://cerius.dk/om-elnettet/ Last accessed: 22-05-2024

Crossroad Galcanizering, 2020. *Galvanized steel vs stainless steel: which is the better choice?* [Online] Available at: https://crossroadsgalvanizing.com/2020/03/03/galvanized-steel-vs-stainless-steel-which-is-the-better-choice/Last accessed: 21-05-2024

CSI, 2020. Why polyamides like rilsan are important. [Online] Available at: https://coatingsystems.com/polyamides-like-rilsan-important/ Last accessed: 19-05-2024

Damberg, H., 2024. 2023: Et vildt vejrår med eflere rekorder – især i den våde kategori. [Online] Available at: https://www.dmi.dk/nyheder/2023-et-vildt-vejraar-med-flere-rekorder-isaer-i-den-vaad Last accessed: 19-04-2024

Davis, Wilder, 2021. Will This New Vaccum Sealing System Keep Your Produce Fresher Longer? [Online] Available at: https://www.epicurious.com/expert-advice/will-this-new-vacuum-sealing-system-keep-your-produce-fresher-longer-article Last accessed: 15-05-2024

Delve, n.d. Semi structured interviews. [Online] Available at: https://delvetool.com/blog/semi-structured Last accessed: 25-05-2025

DESG, 2022. *Hvad er busbar*. [Online] Available at: https://dk.cncbusbar.com/news/what-is-busbar-60486334.html Last accessed: 19-04-2024

DMI, 2024. Klimaatlas. [Online] Available at: https://www.dmi.dk/klimaatlas Last accessed: 19-04-2024

Elasto Proxy, n.d. *Gasket compression explained*. [Online] Available at: https://www.elastoproxy.com/enclosure-gasket-compression/ Last accessed: 23-05-2024

Elgrossisten, n.d. *Installationskabel*. [Online] Available at: https://www.el-grossisten.dk/kabler-ror-kanaler/kabler/installationskabel.html Last accessed: 19-04-2024

Eppinger, D., S., Ulrich, T., K., 2016. *Product Design and Development*. [Online] Available at: https://thuvienso.hoasen.edu.vn/v/web/viewer.html?file=/bitstream/handle/123456789/9147/Contents.pdf?sequence=3&isAllowed=y Last accessed: 17-05-2024

Energinet, n.d. Om os. [Online] Available at: https://energinet.dk/om-os/Last accessed: 19-04-2024

Energistyrelsen, 2023. Forstå din elregning. [Online] Available at: https://old.sparenergi.dk/forbruger/el/dit-elfor-brug/forstaa-din-elregning Last accessed: 20-04-2024

Ewii, n.d. *Hvordan fungerer elmarkedet i Danmark*? [Online] Available at: https://www.ewii.dk/erhverv/el/elmarkedet/Last accessed: 19-04-2024

Figibara, 2017. What is busbar? [Online] Available at: https://figabara.com/en/what-is-busbar/ Last accessed: 30-04-2024

Finanswatch, 2023. Oktobers stormflod ventes at koste 1.2 milliarder i erstatning. [Online] Available at https://finanswatch.dk/Finansnyt/Forsikring/article16700556.ece Last accessed: 19-04-2024

Gillis, A. S., 2023. *Proof of concept (poc)*. [Online] Available at: https://www.techtarget.com/searchcio/definition/proof-of-concept-POC Last accessed: 24-05-2024

Greenpower, 2019. *Tusindvis af kabelskabe får testet deres helbred*. [Online] Available at: https://greenpowerdenmark.dk/nyheder/tusindvis-kabelskabe-faar-testet-deres-helbred Last accessed: 22-05-2024

Interface, 2019. What does class 1 and class 2 mean when it comes to PAT testing. [Online] Available at: https://www.intersafe.co.uk/what-does-class-i-and-class-ii-mean-when-it-comes-to-pat-testing/ Last accessed: 22-04-2024

Jørgensen, S., 1200 elkunder sikres mod en ny Bodil. [Online] Available at: https://www.dr.dk/nyheder/regionale/sjaelland/1200-elkunder-sikres-mod-en-ny-bodil Last accessed: 18-04-2024

Kloecker Metal Corporation, 2024. Why 5052 aliminum is so popular with our cusromers. [Oniline] Available at: https://www.kloecknermetals.com/blog/why-5052-aluminum-is-so-popular-with-our-customers/ Last accessed: 21-05-2024

Kersten, 2024. *Rilsan.* [Online] Available at: ]https://www.kerstencoating.com/coatings/rilsan/ Last accessed: 19-05-2024

Lejkamera, n.d. *GoPro Hero 5.* [Online Image] Available at: https://www.lejkamera.dk/vare/gopro-hero-5/ Last accessed: 23-05-2024

Lewis Cathleen, 2015. The Shapard & Armstrong Spacesuits: 8 Fun Facts. [Online] Available at: https://airandspace. si.edu/stories/editorial/shepard-armstrong-spacesuits-8-fun-facts Last accessed: 15-05-2024

Mcfadyen, S., 2012. Three Phase Power Simplified. [Online] Available at: https://myelectrical.com/notes/entryid/172/three-phase-power-simplified Last accessed: 19-04-2024

MekeltFrom, 2021. 5052 Aluminum vs. AISI 304 stainless steel. [Online]. Available at: https://www.makeitfrom.com/compare/5052-AlMg2.5-3.3523-A95052-Aluminum/AISI-304-S30400-Stainless-Steel Last accessed: 21-05-2024

MetalTek, 2024. 304 vs. 316 StainlessStell: Which one is better? [Online] Available at: https://www.metaltek.com/blog/304-vs-316-stainless-steel-which-one-is-better/ Last accessed: 21-05-2024

NASA, n.d. *Understanding Climate*. [Online] Available at: https://sealevel.jpl.nasa.gov/ocean-observation/understanding-climate/air-and-water/ Last accessed: 09-05-2024

Nexans, u.d. How to apply a bending radius correctly. [Online] Available at: https://www.nexans.nl/en/business/Building-Territories/Building/Distributors/Bending-radius.html Last accessed: 17-05-2024

NicolaskJ, 2024. Sammenligning af alle netselskaber i Danmark. [Online] Available at: https://nicolaskj.dk/sammenligning-af-alle-netselskaber-i-danmark/ Last accessed: 19-04-2024

NSSL, n.d. Severe Weather 101: Flood Basics. [Online] Available at https://www.nssl.noaa.gov/education/svrwx101/floods/ Last accessed: 05-05-2024

Ralcolorchart, n.d. *Overview of all RAL colors*. [Online] Available at: https://www.ralcolorchart.com/ Last accessed: 17–05–2024

Radius, n.d Om elnettet. [Online] Available at https://radiuselnet.dk/om-elnettet/ Last accessed: 22-05-2024

Ritzau, 2023. TREFOR står med en større oprydningsopgave efter stormflod. [Online] Available at: https://via.ritzau.dk/pressemeddelelse/13750659/trefor-star-med-en-storre-oprydningsopgave-efter-stormflod?publisher-Id=13560270&lang=daLlast accessed: 19-04-2024

RS components LTD, n.d. Everything you need to know about cable glands. [Online]. Available at: https://uk.rs-online.com/web/content/discovery/ideas-and-advice/cable-glands-guide Last accessed: 19-04-2024

Southco, 2024. Compression latch. [Online] Available at: https://southco.com/en\_us\_int/e3-223-17 Last accessed: 22-05-2024

Sportkostner, u.d. *Gopro HD Hero* 2. [Online Image] Available at: https://www.sportkostner.com/en/news-events/gopro-hd-hero-2 Last accessed: 23-05-2024

Stephenson, D., 1993. EFFECTS OF URBANIZATION ON SURFACE WATER RUNOFF. [PDF] Available at: https://www.wrc.org.za/wp-content/uploads/mdocs/183-1-93.pdf Last accessed: 25-05-204

Stephensen, E., K., Hver sjette bolig i Danmark er i høj risiko for at blive oversvømmet, viser undersøgelse. [Online] Available at: https://nyheder.tv2.dk/klima/2024-04-08-hver-sjette-bolig-i-danmark-er-i-hoej-risiko-for-at-blive-oversvoemmet-viser-opgoerelse Last accessed: 21-05-2024

Stoubæk, N., 2024. Elproduktion i Danmark – Hvor kommer strømmen fra? [Online] Available at: https://elberegner.dk/guides/elproduktion-i-danmark/Last accessed: 19-04-2024

Sunpower, n.d. *Leakage current*. [Online] Available at: https://www.sunpower-uk.com/glossary/what-is-leakage-current/ Last accessed: 19-05-2024

Unifiedalloys, 2024. Stainless steel vs. Aluminum. [Online] Available at: https://www.unifiedalloys.com/blog/stainless-steel-vs-aluminum Last accessed: 21-05-2024

Zurich, 2023. Three common types of floods explained. [Online] Available at: https://www.zurich.com/en/knowledge/topics/flood-and-water-damage/three-common-types-of-flood Last accessed: 19-04-2024

Walsh, L., 2023. Climate change and flooding. [Online] Available at: https://www.oxfam.org.uk/oxfam-in-action/oxfam-blog/climate-change-and-flooding/ Last accessed: 25-05-2024

#### PDF

Arkema,2022a. *Rilsan*. [PDF] Arkema Inc. Available at: https://www.arkema.com/files/live/sites/shared\_arkema/files/downloads/countries/Japan/20230804\_Rilsan-Pebax-brochures/RILSAN%C2%AE%20General%20Brochure\_size%20reduced.pdf Last accessed: 02-05-2024

Arkema, 2022b. *Electrostatic spraying process* [PDF] Arkema Inc. Available at: https://hpp.arkema.com/files/live/sites/shared\_arkema/files/downloads/HPP/product-brochures/RFP/rfp-br-electrostatic-spraying-process-optimizedpdf.pdf Last accessed: 02-05-2024

Arkema, 2022c. Fluidized bed dipping process [PDF] Arkema Inc. Available at: https://hpp.arkema.com/files/live/sites/shared\_arkema/files/downloads/HPP/product-brochures/RFP/rfp-br-fluidized-bed-dipping-process-optimizedpdf.pdf Last accessed: 02-05-2024

Dubberly, H., n.d., How do you design? [PDF]. San Fransisco: Dubberly Design Office

Hævnenes Hus, u.d. *Complaint guidelines*. [PDF] Available at: https://naevneneshus.dk/media/9791/complaint-guidelines-klfu.pdf Last accessed: 17-05-2024

Kirby Morgan Dive Systems, n.d. *Neck Ring Assemby, Locking Collar and Front Stand Offs Contents*. [PDF]. Available at: https://www.kirbymorgan.com/sites/default/files/2022-02/neck-ring-assembly-locking-collar-front-stand-offs-220222015.pdf Last accessed: 18-05-2024

Plastifil, 2005. *Rilsan PA11.* [PDF] Plastifil SA. Available at: https://plastifil.ch/wp-content/uploads/2022/04/Rilsan-PA-11\_.pdf Last accessed: 06-05-2024

#### **Books and articles**

Bagger, K. & Sperschneider, W., 2003. Ethnographic Fieldwork Under Industrial Constraints: Toward Design-in-Context

Dorst, K & Cross, N, 2001. Creativity in the Design Process: Co-Evolution of Problem-Solution. Design Studies22(5):425-437

Haase, L.M. & Laursen, L.N., 2022. Designing for Longevity: Expert Strategies for Creating Long-Lasting Products. Milton:Taylor & Francis Group

Mabogunje, A., Hansen, P.H.K., Berg, P., 2013. Exploring Innovation – A Language Approach. Aalto University. PublicationSeries Science

Malinin, L., 2018. Situated Design-Thinking in Architectural Practice: Analyzing and Extending Schön's Epistemology. Ardeth.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K.-H. (2007). Engineering Design: A Systematic Approach (3rd ed.). Springer.

Ries, E., 2011. The Lean Startup. 1. ed. edn. New York: Crown/Archetype

Schrage, M., 2006. Cultures of Prototyping. Bringing Design to Software, May 2006

Tollestrup, C. & Laursen, L.N., 2017. Design Thinking - A Paradigm

Verganti, R., 2003. Design as brokering of languages: Innovation strategies in Italian firms. Design Management Journal, 14(3), 34–42.

# LIST OF ILLUSTRATIONS

#### **PDF**

Naturskaderådet, 2023. *Stormflod-21-oktober-2023*. [PDF] Naturskaderådet. Available at: https://www.naturskaderaadet.dk/nyheder/stormraadet/pressemeddelelser/20231021-naturskaderaadet-her-var-der-stormflod-den-20-21-oktober-2023/ Last accessed: 19-04-2024

#### Websites

Amazon, 2024. Food Organizer, Food Storage Contaainer, Pressure Switch Lid, Thickened Space-saving for Grain for Rice (Broleikrg36idtu9-13. [Online Image] Available at: https://www.amazon.com/Organizer-Container-Thickened-Space-saving-BROLEOkrg36idtu9-13/dp/BOCRSQNR9W Last accessed: 17-05-2024

Amazon, 2024. M5 x 15 A2 stainless steel flat geat knurled rivet nuts ricnuts nutserts – 10 pack. [Online Image] Available at: https://www.amazon.co.uk/Stainless-Steel-Knurled-Rivnuts-Nutserts/dp/B07W5P9VXM?th=1 Last accessed: 23-05-2024

Ankerstjerne, M.,2023. *Havnen er totalt smadret, siger havnefoged efter uvejr.* [Online image] Available at: https://nyheder.tv2.dk/2023-10-21-havnen-er-totalt-smadret-siger-havnefoged-efter-uvejr Last accessed: 19-04-2024

Apple Rubber, 2021. *O-ring vs gasket: Which seal is the best for you application?* [Online Image] Available at: https://www.applerubber.com/blog/o-ring-vs-gasket-which-seal-is-best-for-your-application/ Last accessed: 15-05-2024

Bels, n.d. *Cabinet System Vejskab 600x850x310 grå*. [Online Image] Available at: https://bels.dk/cabinet-system-ve-jskab-600x850x310-gra-5709832080598 Last accessed: 17-05-2024

Christoffersen, E. 2024. Se billeder og video: Oversvømmede veje, pumper på hårdt arbejde og biler under vand. [Online image] Available at: https://koldingnyheder.dk/se-billeder-og-video-oversvoemmede-veje-pumper-paa-haardt-arbejde-og-biler-under-vand/ Last accessed: 30-04-2024

Direct Industry, n.d. Wall.mounted junction box. [Online Image] https://www.directindustry.com/prod/takachi-electronics-enclosure-co-ltd/product-187747-2500537.html Last accessed: 19-04-2024

Faaborgrøgericafe, 2023. Stormflod 20/10 + 21/10 - 2023. [Online image] Available at: https://faaborgroegericafe.dk/stromflod-51-2017/ Last accessed: 19-04-2024

Freepik, 2024, A soda can covered in condensation. [Online Image] Available at: https://sealevel.jpl.nasa.gov/ocean-observation/understanding-climate/air-and-water/ Last accessed: 22-05-2024

Freepik, 2024. *Healthy jojoba oil treatment composition*. [Online Image Available at: https://www.freepik.com/free-photo/healthy-jojoba-oil-treatment-composition\_15738714.htm#fromView=search&page=1&position=16&uuid=ffd81765-0fe9-4ef3-a332-7a1626ae8299 Last accessed: 19-05-2024

Gardenseedsmarket, n.d. *Container taske – Big–Bag.* [Online image] Available at: https://gardenseedsmarket.com/container-taske-big-bag-90-x-90-x-110-cm.html Last accessed: 30-04-2024

Grandville, n.d. Åkvarteret er Koldings nye midtbykvarter. [Online image] Available at https://grandville.dk/projekter/aakvarteret-er-koldings-nye-midtbykvarter/ Last accessed: 20-04-2024

Hummel, u.d. *Gummistøveler*. [Online Image] Available at: https://www.hummel.dk/rubber-boot-jr.-sports-yel-low/206511-5001.html Last accessed: 23-05-2024

Høier, J., 2024. *Vestre Ringgade syd for vandmassen*. [Online Image] Available at: https://www.facebook.com/pho-to/?fbid=10160398699903533&set=pcb.10160589256927950 Last accessed: 20-04-2024

Interface, 2019. What does class 1 and class 2 mean when it comes to PAT testing. [Online Image] Available at: https://www.intersafe.co.uk/what-does-class-i-and-class-ii-mean-when-it-comes-to-pat-testing/ Last accessed: 22-04-2024

ISO, 2003. IEC 60417 - 5172 Class II equipment. [Online image] Available at: https://www.iso.org/obp/ui#iec:grs:60417:5172 Last accessed 22-04-2024

Interface, 2019. What does class 1 and class 2 mean when it comes to PAT testing. [Online] Available at: https://www.intersafe.co.uk/what-does-class-i-and-class-ii-mean-when-it-comes-to-pat-testing/ Last accessed: 22-04-2024

Istuck, n. d. *Air conditioner service man*. [Online Image] Available at: https://www.istockphoto.com/photo/air-conditioner-service-backgrounds-gm1171253308-324416158?searchscope=image%2Cfilm Last accessed: 18-04-2024

Istuck, n.d. Electric control cabinet on the pole. waterproof steel enclosure for and control of high voltage electrical system on concrete poles on blue sky. stock photo. [Online Image] Available at: https://www.istockphoto.com/photo/electric-control-cabinet-on-the-pole-waterproof-steel-enclosure-for-and-control-of-gm2151924989-572977771?searchscope=image%2Cfilm Last accessed: 15-05-2024

iStock, n.d. *Handyman using cualk gun when fixing balcony door stock photo.* [Online Image] Available at: https://www.istockphoto.com/photo/handyman-using-caulk-gun-when-fixing-balcony-door-gm1498958322-520833218?searchscope=image%2Cfilm Last accessed: 18-05-2024

Istock, u.d. *Man opens door force stock photo*. [Online Image] Available at: https://www.istockphoto.com/photo/man-opens-the-door-force-gm614047402-106131233?searchscope=image%2Cfilm Last accessed: 15-05-2024

JBL, 2024. Waterproof-højtalere. [Online Image] Available at: https://dk.jbl.com/waterproof.html Last accessed: 23-05-2024

Istuck, n.d. System Control photo. [Online Image] Available at: https://www.istockphoto.com/photo/system-control-gm1629383577-532357990?searchscope=image%2Cfilm Last accessed: 18-04-2024

Kirby Morgan Dive Systems, n.d. NNeck Ring Assembly, SM. [PDF] Available at:https://aquatic.dk/produkt/5586/neck-ring-assembly-sm/ Last accessed: 18-05-2024

Lemvig-Müller, 2015. *CP6 målerskab til stikbenstilslutning*. [Online Image] Available at: https://www.lemu.dk/catalog/products/cp6-maalerskab-til-stikbenstilslutning/7811111013 Last accessed: 17-05-2024

Lewis Cathleen, 2015. The Shapard & Armstrong Spacesuits: 8 Fun Facts. [Online Image] Available at: https://airand-spaces.si.edu/stories/editorial/shepard-armstrong-spacesuits-8-fun-facts Last accessed: 15-05-2024

Knudsen, L. & Beckmann, A., Trap Danmark, 2021. *Befolkning og boliger i Stevns Kommune*. [Online image] Available at: https://trap.lex.dk/Befolkning\_og\_boliger\_i\_Stevns\_Kommune Last accessed: 19-04-2024

Made-in-cChina, 2024. *Kisa inflatable dinosaur pool float blow up animal ride on toys*. [Online Image] Available at: https://matt1991.en.made-in-china.com/product/gnDpdNSGnokc/China-Kids-Inflatable-Dinosaur-Pool-Float-Blow-Up-Animal-Ride-on-Toys.html Last accessed: 23-05-2024

Nexans, n.d. How to apply a bending radius correctly. [Online] Available at: https://www.nexans.nl/en/business/Building-Territories/Building/Distributors/Bending-radius.html Last accessed: 17-05-2024

NicolaskJ, 2024. Sammenligning af alle netselskaber i Danmark. [Online image] Available at: https://nicolaskj.dk/sammenligning-af-alle-netselskaber-i-danmark/ Last accessed: 19-04-2024

Pacnvac, 2026. How it works: The science behind pac 'n vac food container. [Online image] Available at: https://www.pacnvac.co.uk/pacnvac-products/how-it-works/ Last accessed: 17-05-2024

Santopseal, 2022. What are the benefits of using rubber seals & gaskets? [Online Image] Available at: https://www.santopseal.com/what-are-the-benefits-of-using-rubber-seals-gaskets/ Last accessed: 15-05-2024

Sack It, n.d. Ambience – Lamp intelligent + Aalborg base. [Online Image] Available at: https://sackit.dk/products/ambience-lamp-intelligent-aalborg-base Last accessed: 23-05-3024

Southco, 2024. Compression latch. [Online Image] Available at: https://southco.com/en\_us\_int/e3-223-17 Last accessed: 22-05-2024

Store, u.d. IP68 high performance waterproof enclosure wg series products takachi manufacturer of electronics enclosures and industrial enclosures. [Online Image] Available at: https://superlagar.live/product\_details/97871051.html Last accessed: 115-05-2024

Sørensen, P. [Received Image]

Sørensen, K., P. [Received Image]

Trefor, 2024. Kort over skabe påvirket i oktober. [Received Image].

Triarca, n.d. *Trilite*. [Online Image] Available at: https://www.triarca.dk/dk/produkter/automation/trilite/ Last accessed: 17-05-2024

Wiencken, B. L., 2023. Oversvømmelse Kolding Jernbanebro. [Online Image] Available at: https://www.facebook.com/photo/?fbid=10231161921021528&set=pcb.10160424068577950 Last accessed: 20-04-2024