Appendices

Assessing and improving the circularity of EVBox's commercial AC chargers

Isabelle Laros
4306465
31-08-2021

B. Project brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Laros 4748
initials: I given name: Isabelle
student number: 4306465
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ○ DfI ○ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ○ Honours Programme Master
specialisation / annotation: ○ Medisign ○ Tech. in Sustainable Design ○ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Conny Bakker dept. / section: Circular Product Design
** mentor: Sagar Dangal dept. / section: Design for Sustainabilit
2nd mentor: Baptiste Sené
organisation: VanBerlo
city: Eindhoven country: Netherlands

comments (optional): I will be working as a graduate intern at Van Berlo working on the project for EVBox.

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Conny Bakker date - - signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 30 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name J. J. de Bruin date 23 - 02 - 2021 signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED NOT APPROVED

Procedure: ★ APPROVED NOT APPROVED

remark: - title is unclear (EVBox)

comments

name Monique von Morgen date 02 - 03 - 2021 signature

Initials & Name I Laros 4748 Student number 4306465

Title of Project Circular charging stations for EVBox

Circular charging stations for EVBox

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 15 - 02 - 2021 16 - 07 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

As the depletion of our finite supply of natural resources is drawing closer and closer, humanity has to shift from the current linear economy to a circular economy. The circular economy is regenerative and restorative by design and is based on the following three principles: designing out waste and pollution, keeping products and materials in use and regenerating natural systems, (Ellen MacArthur Foundation, 2021). This circular approach enables humanity to capture and retain value of products for longer periods of time through reusing, repairing, refurbishing, remanufacturing and recycling, see figure 1.

The European Commission has embraced the circular economy and is gradually implementing legislation for its members to follow. Examples are the Waste Electrical and Electronic Equipment (WEEE) directive, the European Green Deal (European Commission, 2019) and the Circular Economy Action Plan, (European Commission, 2020).
On national level, governments are taking action as well. The Dutch government aims, for example, for all new bought cars to be emission free in 2030, (Rijksoverheid, 2020).

One aspect of the aforementioned energy transition is the replacement of internal combustion engine vehicles (ICEV) with electric vehicles (EV). Technological advances, supportive policies and customer's growing sustainability awareness have driven the use of EV's to an all-time high, (IEA, 2020; CBS, 2020). The transition has a great impact on society as new charging stations have to be placed to provide power to these vehicles.

EVBox is a company that produces these EV charging stations that can be used in domestic-, semi-commercial- and commercial contexts. Their aim is to build a sustainable future by providing flexible and scalable electric vehicle charging solutions. As an e-mobility actor, sustainability is at EVBox's core; in combination with the customer's pull and legislative push the company has started developing interest in becoming more circular, in order to be ahead of the curve and remain market leader, (VanBerlo, 2018).

VanBerlo, part of Accenture, is a design agency that creates value for partners through innovative service- and product design and have previously collaborated with EVBox on circularity projects. Previous projects include the development of a list of Sustainable Product Design Guidelines for EVBox's mechanical engineers and the clarification of EoL scenarios and -strategies for one of EVBox's products. Finding new strategies to implement circular design in EVBox's portfolio and determining which loops are most valuable to close is the basis of the next step in their ongoing partnership. Together with the TU Delft, a joint graduation project was set up to assess and enhance the circularity of EVBox's products.

With the use of alumni Francesco de Fazio's Disassembly map the current and future EVBox portfolios can be evaluated. The disassembly tool, in figure 2 used on a vacuum cleaner, enables users to evaluate the repairability of products by showing parts and needed actions in sequential or parallel order.

I will be working on this project as a graduate intern at Van Berlo, who have been collaborating with EVBox for 5 years. The project will be done under supervision of Conny Bakker (chair) and Sagar Dangal (mentor) from the TU Delft.

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Initials & Name I Laros 4748 Student number 4306465

Title of Project Circular charging stations for EVBox

introduction (continued): space for images

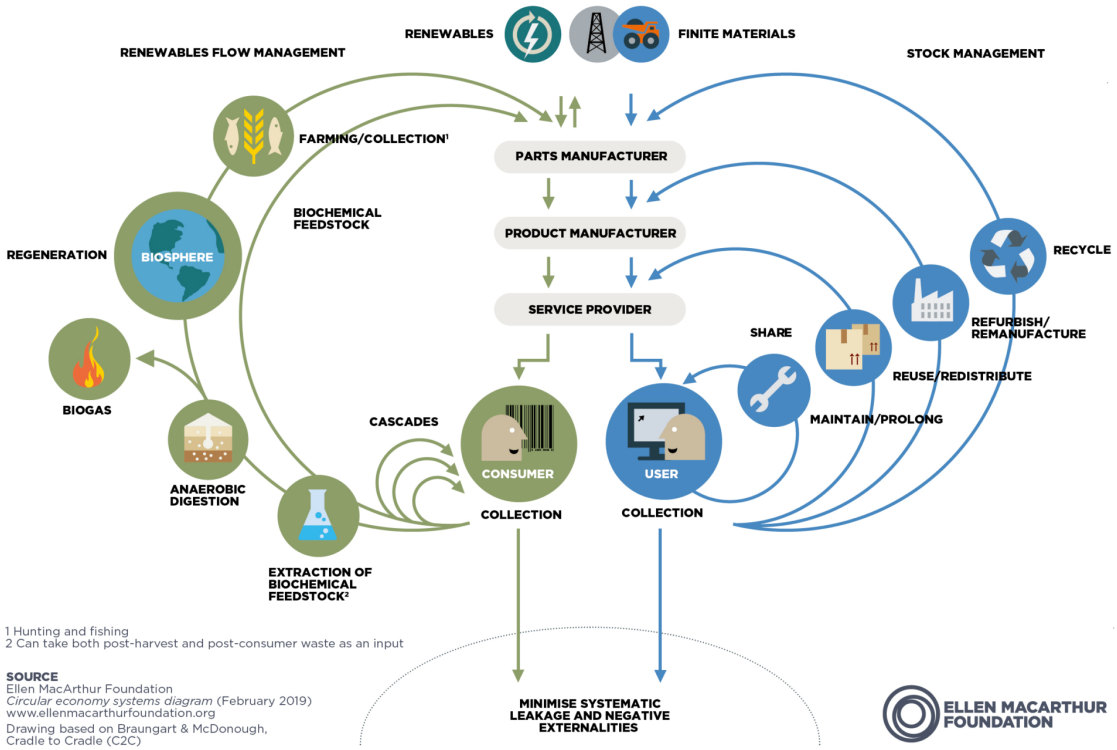


image / figure 1: The butterfly diagram shows how loops can be closed

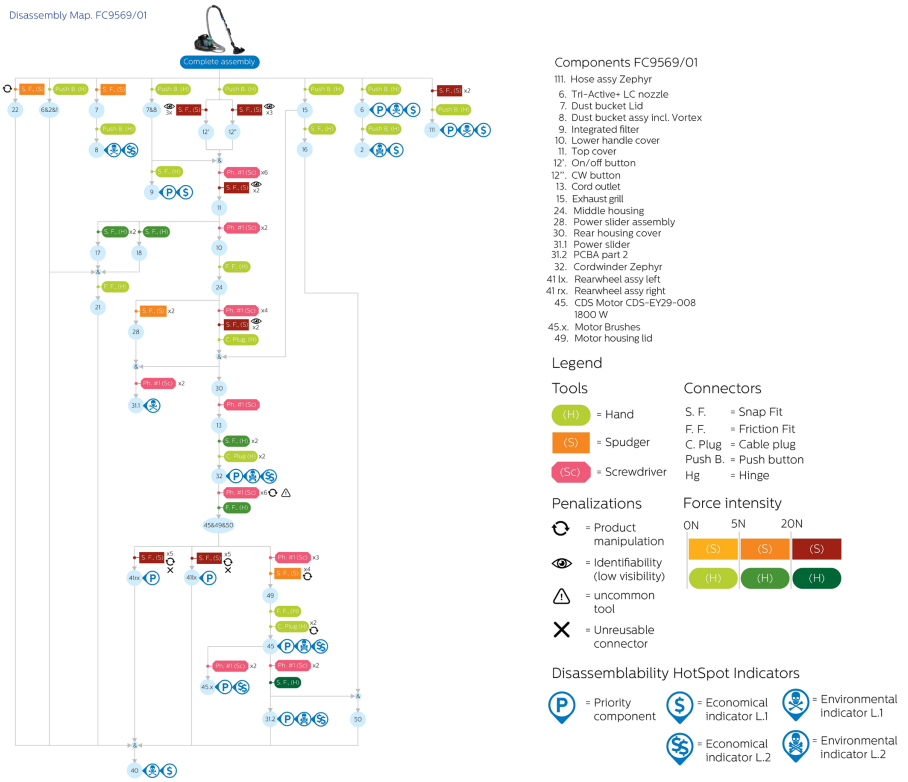


image / figure 2: Example of a completed disassembly map for a vacuum cleaner

Initials & Name I Laros 4748 Student number 4306465

Title of Project Circular charging stations for EVBox

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

As of now, even though EVBox is heavily involved with the energy transition, it is still searching for ways to implement circularity during product development. This joint project between EVBox, Van Berlo and TU Delft will address this matter by assessing and enhancing the circularity of the charging stations in EVBox's current and future portfolios. The project will focus on semi-commercial- and commercial B2B AC chargers; products that can be found in, for example, office- and public parking lots. The project will consist of analysing the current strategy and impact of products (making it insightful and measurable), making suggestions on strategy improvement for future products, illustrative implementation and measuring of impact of said suggestions and finally the definition of a circular product strategy.

- First, it is important to determine which products are suitable to make disassembly maps of. For example, based on when the product will be decommissioned and how complex a product is.
- Furthermore, the Disassembly map has only been used on B2C products such as vacuum cleaners (de Fazio, 2019) and child car seats (Vermaat, 2020), which means the tool has yet to be optimised for other types of products such as charging stations. Furthermore, ways of implementation for B2B products is yet to be explored.
- Finding out which loop(s) are suitable for future strategy is the next important issue to address. This will ensure that EVBox's products WILL actually be circular, instead of just being designed circularly. The Disassembly map focuses on product repairability, which also affects refurbishability and remanufacturability. As the project will be on B2B chargers which are maintained and decommissioned by professionals, the focus loop will likely be refurbishability and remanufacturability.
- When improving circularity of products, it is essential not to compromise context- and user needs such as operability, safety and resistance to weather and vandalism. Especially since all charging stations are placed outside and are subjected to the elements.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

This graduation project aims to standardize a Circularity approach for EVBox's (semi-)commercial portfolio via the use of the Disassembly Map tool. Based on the findings an illustrative redesign will be made and a methodology for supporting EVBox with implementing circularity will be proposed.

To familiarise myself with the world of EV and electric chargers, a context analysis will be done first. Life cycle maps of 3 predetermined products in the (semi-)commercial segment will be made.

Then disassembly maps of said products will be made. The tool can give an indication of where and how disassembly of EVBox's products can be improved. Then, through reversed logistics mapping a map of the value flows (financial, material) for the (semi-)commercial EV chargers can be created. A focus loop can be chosen based on the findings.

From the context analysis, disassembly maps and reversed logistics map insights, a list of improvements and suggestions for product development and improvements of the Disassembly map tool can be made.

To illustrate ways to implement these improvements, a redesign for one of EVBox's products will be proposed through sketching and a CAD model. If needed, prototypes can be used to demonstrate even further.

Finally, a circular design methodology will be proposed. This will be displayed with at least a poster and potentially a video, booklet or other promotional material for future reference for all EVBox employees.

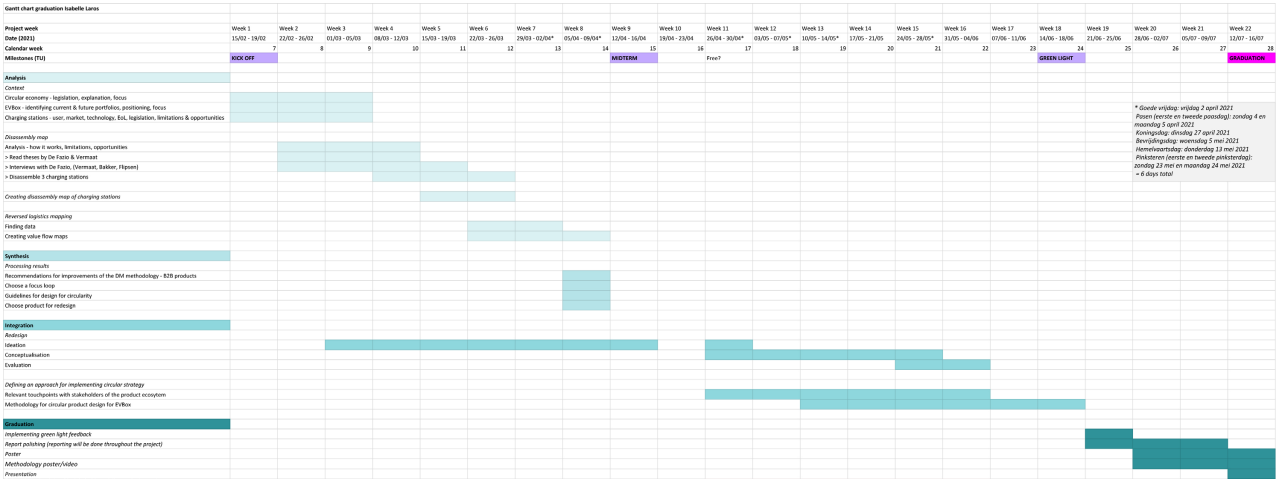
Initials & Name I Laros 4748 Student number 4306465

Title of Project Circular charging stations for EVBox

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 15 - 2 - 2021 16 - 7 - 2021 end date



The graduation project will run from Monday the 15th of February to Thursday the 15th of July. Due to personal and public holidays the total duration of the project will be 22 weeks.

The project will consist of the following 4 phases:
Analysis: to familiarize myself with (the context of) EVBox, circular design strategies and using the Disassembly map. The analysis will be done by doing literature- and field research. Interviews with EVBox and VanBerlo employees will provide insights into the products and their use. Interviews with students and employees from the TU Delft will provide insights in the (use of) the Disassembly map.
Synthesis: distilling all findings into a set of improvements for design for a to be determined loop, and into recommendations for improving the Disassembly map (for B2B products).
Integration: consists of the development of a redesign and the development of a circular product design methodology for EVBox.
Graduation: this phase is for wrapping up the entire project and preparing the deliverables.

Milestones:
Kick-off meeting 15th of February
Midterm 13th of April
Green light 18th of June
Graduation ceremony 15th of July

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MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I feel that it is part of my role as a designer to help humanity transition to a circular future. This project resonates with me on multiple levels as it is both on a smaller in-company scale (helping EVBox to be more circular product-wise) and on a larger societal scale (indirectly helping society transition from ICEV to EV). Its contents lie within my field of interests as I have a passion for the circular economy and I truly believe it is the only way forward. Moreover, the project allows me to focus on multiple aspects of product design: from analysis to design to recommendations. All of which fit well with my masters programme Integrated Product Design.

I am excited to put my knowledge of the circular economy and my skills as a designer to the test in a professional context. However, I am most excited about learning even more. Working closely together with circular- and industrial design engineers at Van Berlo and product managers and engineers at EVBox will surely give me plenty of new insights that I can use throughout my future career.

Learning objectives:
Learning about the professional work environment of a design agency, in this case Van Berlo.
Learning more about electric vehicles and the opportunities and limitations of the transition from ICEV and EV.
Improving my Adobe Illustrator skills, as I have mostly prefered to work with Photoshop.

CBS, (2020). Bijna 200 duizend stekkerauto's. Retrieved from https://www.cbs.nl/nl-nl/nieuws/2020/16/bijna-200-duizend-stekkerauto-s

De Fazio, F. (August, 2019). Enhancing consumer product repairability - A case study on vacuum cleaners. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A810db9a6-9718-4451-8f8f-67ad0cdccad9

Ellen MacArthur Foundation, (2013). Towards the circular economy - Economic and business rationale for an accelerated transition. Retrieved from https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition

IEA, (2020). Global EV outlook 2020. Retrieved from https://www.iea.org/reports/global-ev-outlook-2020

Rijksoverheid, (2021). Overheid stimuleert milieuvriendelijker rijden. Retrieved from https://www.rijksoverheid.nl/onderwerpen/auto/overheid-stimuleert-milieuvriendelijker-rijden

Vermaat, B. (August, 2020). Design for refurbishment of child car seats - Towards circular safety critical products. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A1d77f13b-8005-4cac-aa8d-9350171f158c

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name I Laros 4748 Student number 4306465

Title of Project Circular charging stations for EVBox

C. Brainstorm session #1

Remanufacturing

''Remanufacturing is the process of **returning a used product to like-new condition with a warranty to match** (Ijomah, 2002). The process includes disassembly, cleaning, reprocessing, testing and and reassembly, and parts which cannot be brought back to original quality are replaced, meaning **the final remanufactured product will be a combination of new and reused parts.** Detailed description of the remanufacturing process can be found in (Ijomah, 2007; Seitz and Wells, 2006; Sundin, 2004).''
(Hatcher et. al., 2011)

Design for Remanufacturing + Design for disassembly

Technical solutions for remanufacturing are centered around product design to facilitate **the remanufacturing process, which includes disassembly, cleaning, reconditioning, testing, and reassembly. Redesign proposals should accommodate these steps.**

Disassembly in the remanufacturing process should be:

- Reducing dis- and reassembly times
- Materials and forms appropriate for repetitive remanufacturing
- Mechanisms in product or component to ensure the return of components

Meaning:

- Non-destructive disassembly
- Low product and component complexity
- Fastening methods

Aim of this session

Finding directions for shortening disassembly time and decreasing the number of disassembly steps to make Iqon more suitable for remanufacturing

- Playing with the Disassembly Map to find redesign opportunities for a remanufacturing scenario following the three methods of **clumping, trimming and surfacing,** (Flipsen, 2020).

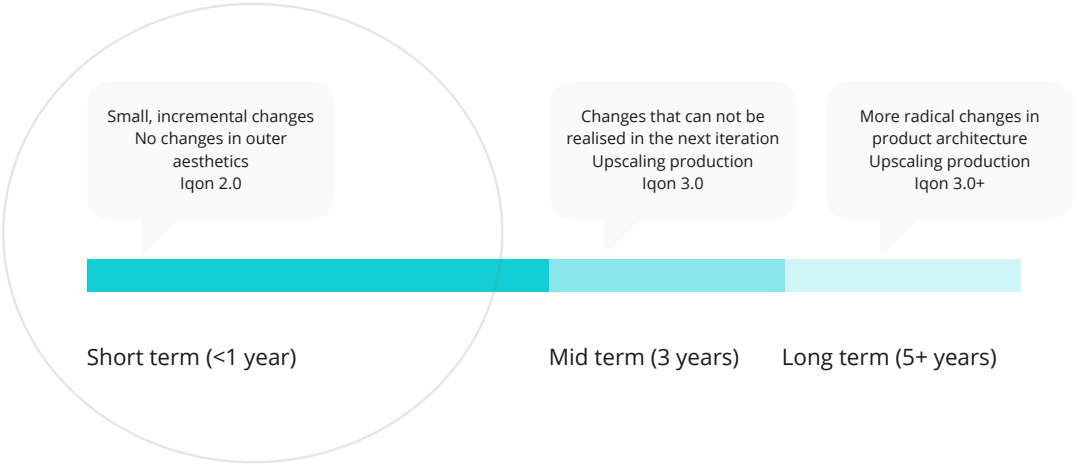
Three methods

Clumping
Parts should be grouped according to their EoL scenario and frequency of failure, facilitating repair, refurbishing, remanufacturing, harvesting and recycling operations.

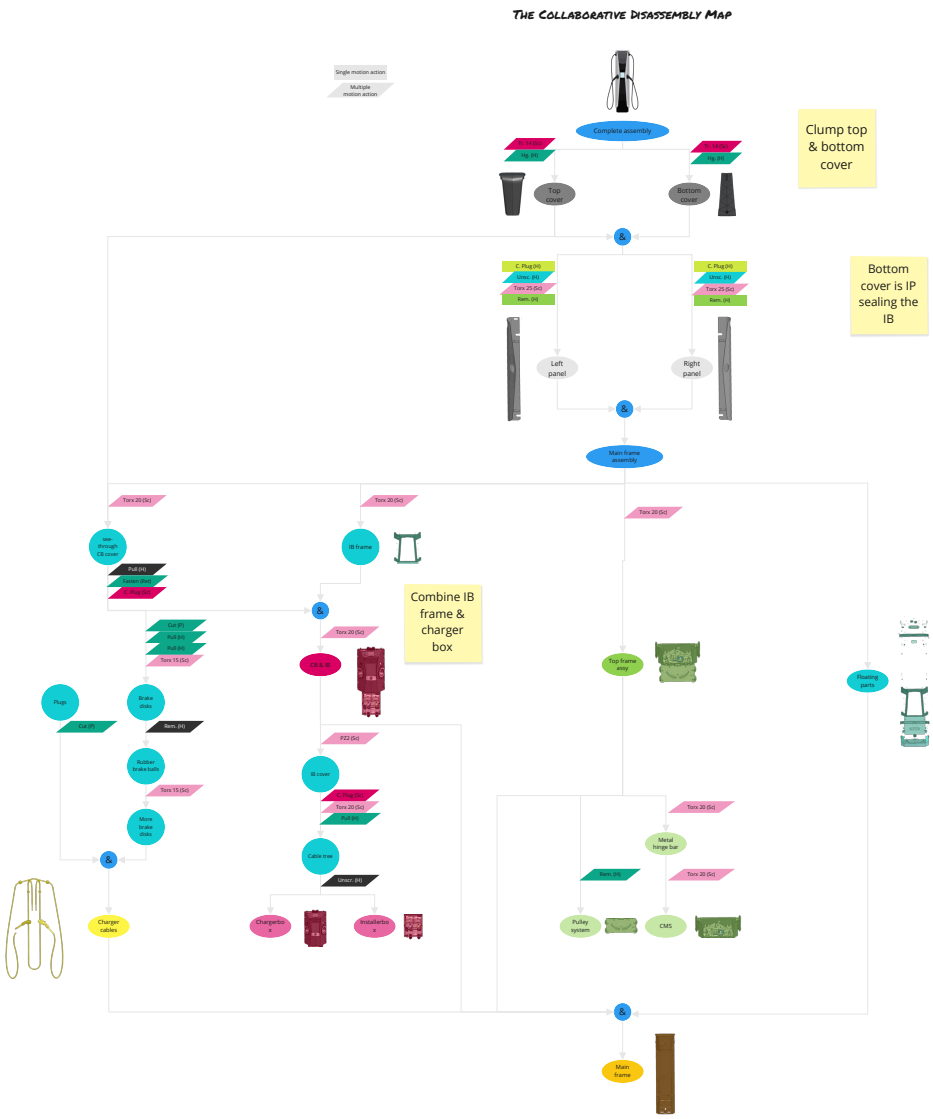
Surfacing
Priority parts should be the easiest and quickest to reach, placing them in the upper layers of the disassembly map.

Trimming
Omit or combine components to minimize the number of components and disassembly steps.

Timeline



Clumping



backbone: attach floating elements to one part that can be taken out at once.

Aluminum cover that doesn't need painting and can be sandblasted.

Click fasteners to loosen the cables?

Repair hatch that can be opened to reach the critical parts.

Change disassembly order to start with side panels

click side panels to the frame?

combine bottom cover with installer box cover

Integrate connection of side panel to custom installer box

Combine IB frame with another part

Long lasting paint on Makrolon covers

Assemble bottom cover and installer box to reach kwh meter quicker

Seperate plug and chargecable?

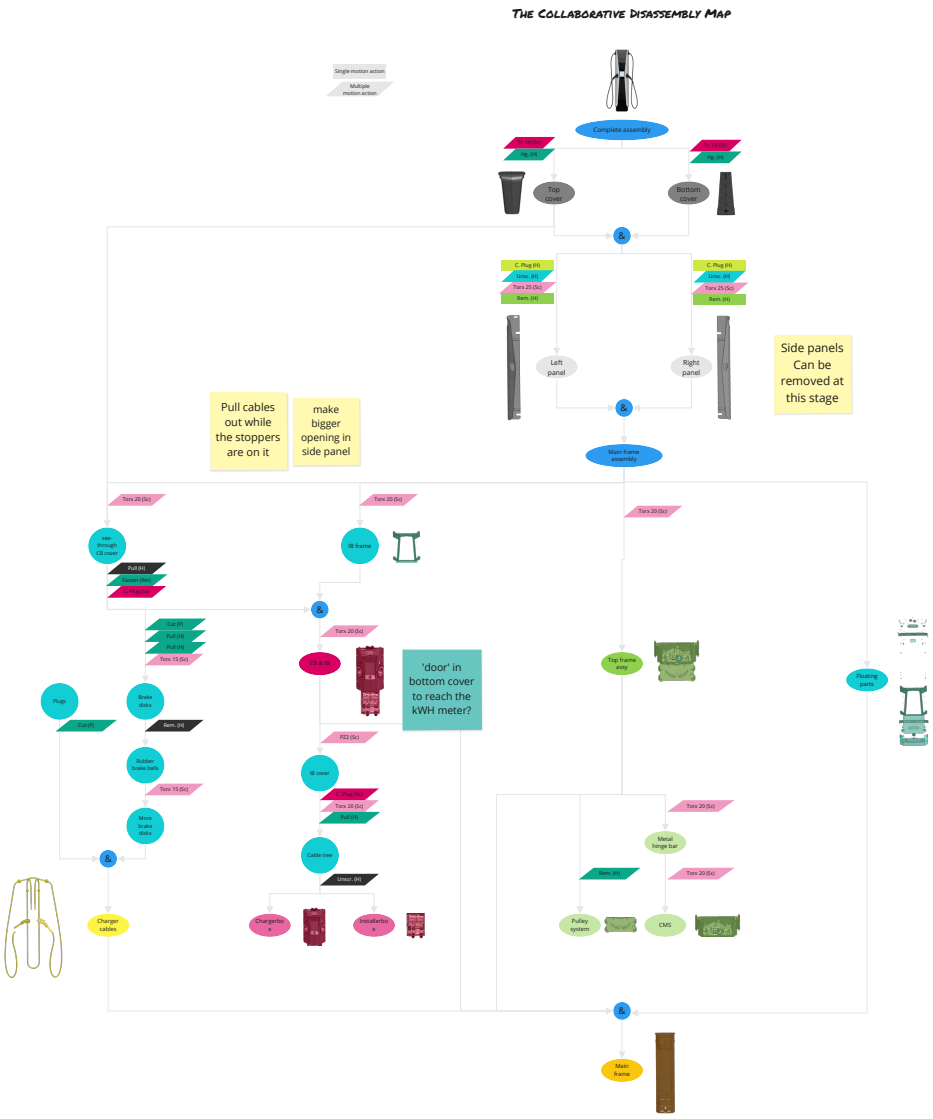
partnership with a supplier?

Mark alu part with materials properties

create one front cover for chargerbox and installer box

How easy would it be to steel parts?

Surfacing



Use connector to split cable in two

Disrupt US market to only sell products with outlet instead of cable

Do we want to remove all stoppers from cables?

remove stopper screws, use clickers?

Use in between part to connect wires to Kwh meter in one go

Access from the back → Different side panel split lines

Trimming

Disassemble floating parts with (air) pressure

use rivits to easily remove by drilling

Clamping rings for the PMMA plates instead of tape

Look into tape that is 'easy' to remove - 3M

Fix plates mechanically instead of with glue → Fold strip around PMMA plate

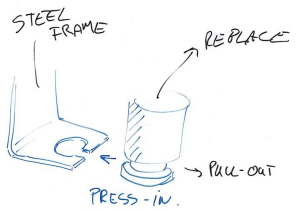
Custom installerbox to combine with IB frame and other functionalities

Lift product in a jack-like manner instead of plastic base part

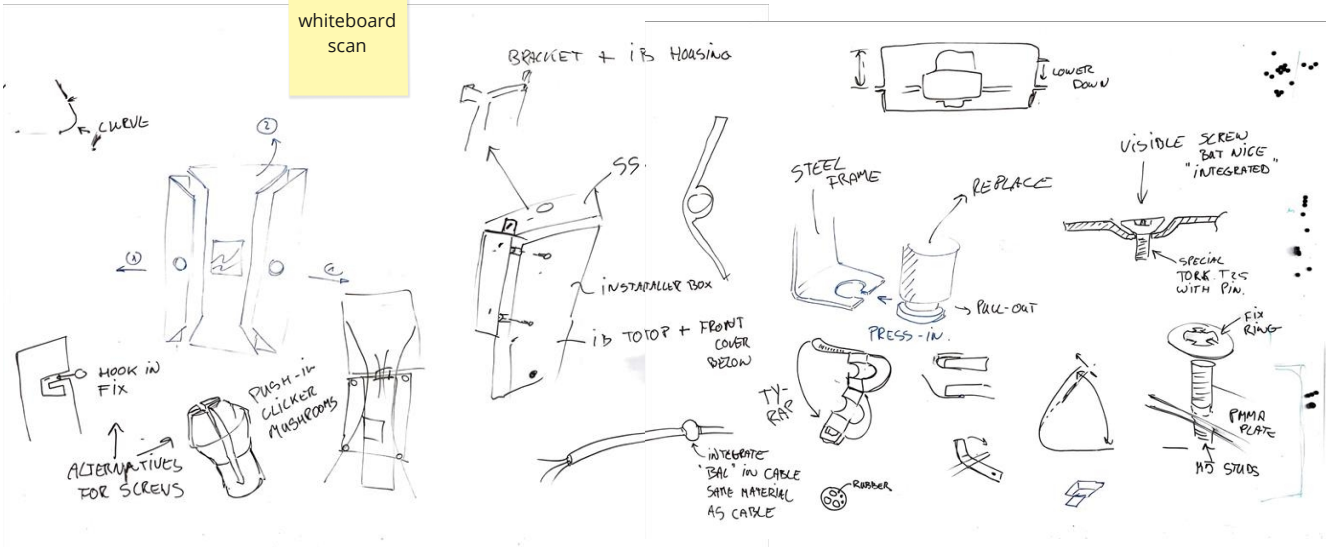
Initial ideas and sketches

visible surfaces can be refurbished in 2 ways:
- Add new layer (paint/coating/sticker or wrap)
-remove layer and add new surface structure

remove parts with air pressure (like bicycle handlebars)



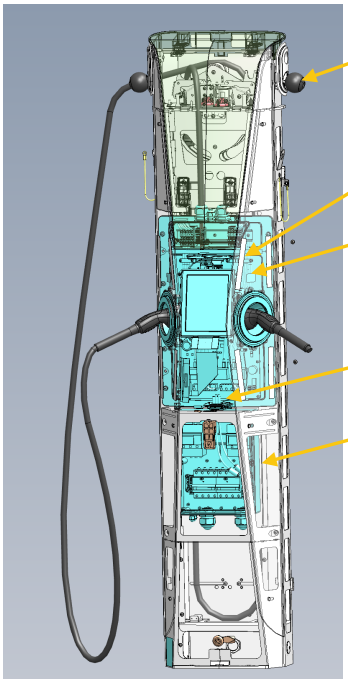
whiteboard scan



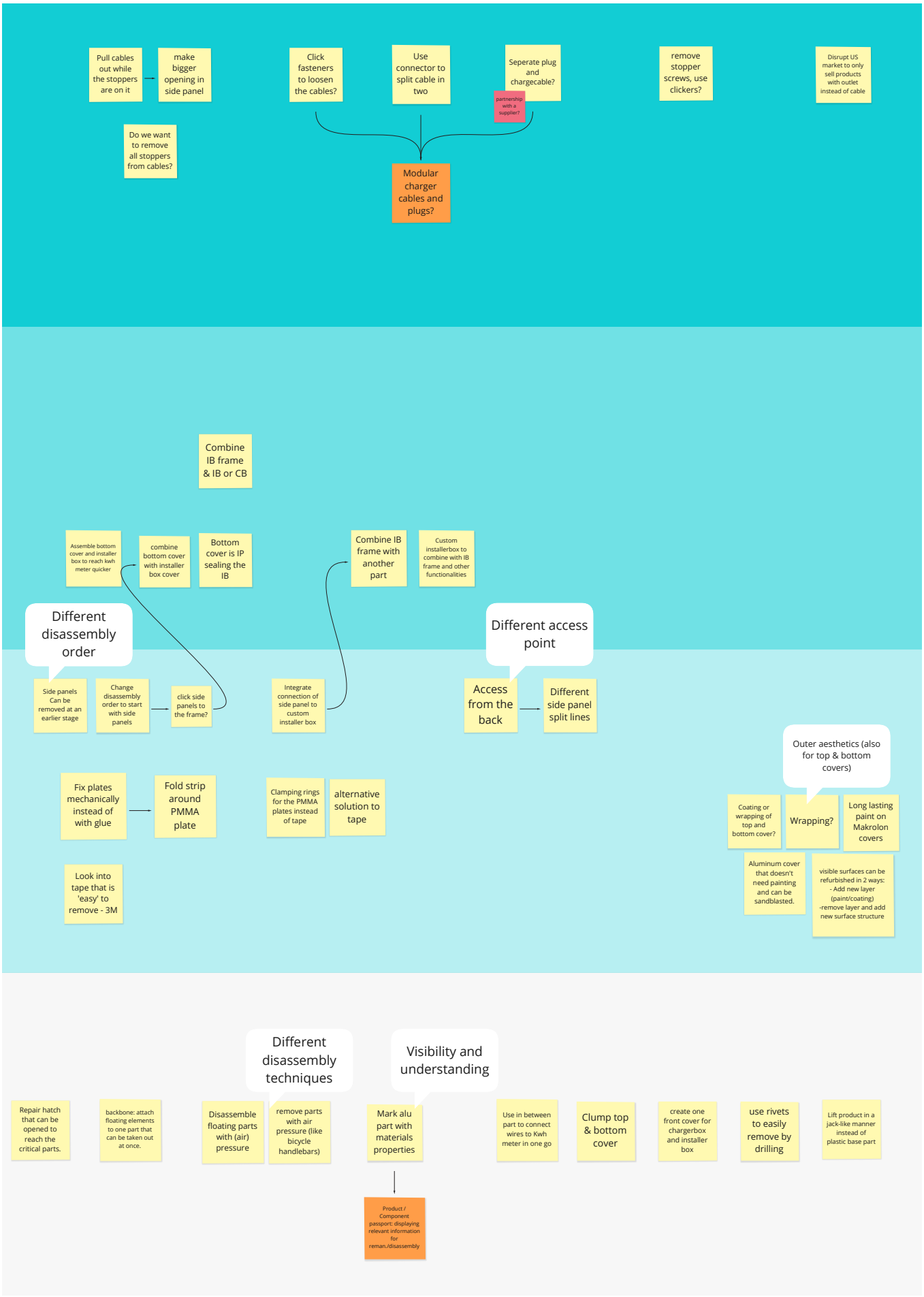
Powder coating
1 front cover for CB & IB
IB frame →
IB stainless steel cover } Combine
Press-in rubber knobs
Cable & Plug → Separable (what actually breaks? → Can you reuse the cable?)
Covers & Panels
Bottom Cover & IB cover for example. IB IP55
No screws on outside
Switch side panels & Covers
Break balls & disks
IB & CB combine with other functionalities

Do we want the top panel as the last step?
Special tool?
How easy do we want the disassembly to be?
Combine bottom cover
Combine top with top frame assy
Top → Side panels → Bottom
15 times opened in its lifetime
Tolerances sidepanels
Connectors are very expensive
Prevent cable from being pulled out & moving inside the product.
Side panel opening bigger so cable + stoppers can be pulled out.
Releasable tie-wrap.
Clever mirrored break disks/stoppers → you need clamping jig.
Narrower cover to remove before this side panel.

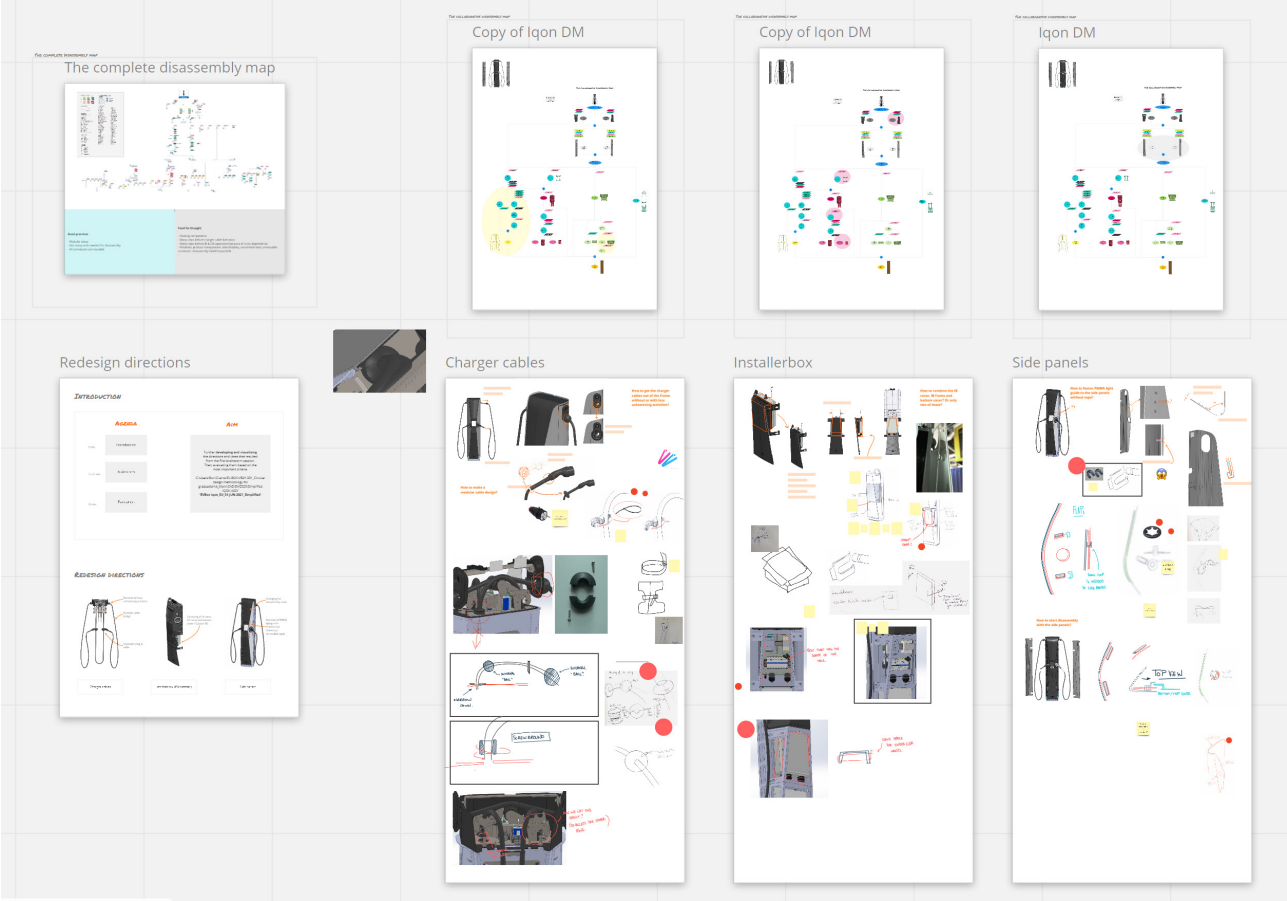
Combined back cover IB & CB, but 2 top cover
More distance between IB & CB? → Tube?
Custom installerbox
Access from the back } there's 2 'skins' frame & panels.
Different panel split lines }
Aluminium extrusion
Rivets can be easily removed with a drill → Cheaper than welding.
Hook in floating parts.
What are the requirements of Reman.??
How important is the
Different kind of tape? → 3M
ADA → US requirements
Custom installerbox → It's not cheap now.



Clustering post-its



D. Brainstorm session #2



Introduction

Agenda

5 min.	Introduction
3 x 25 min.	Brainstorm
15 min.	Evaluation

Aim

Further **developing and visualising** the directions and ideas that resulted from the first brainstorm session. Then, evaluating them based on the most important criteria.

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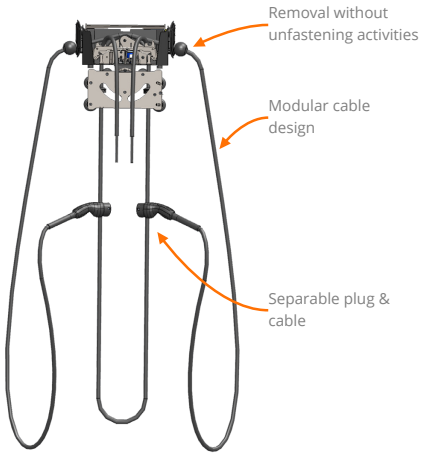
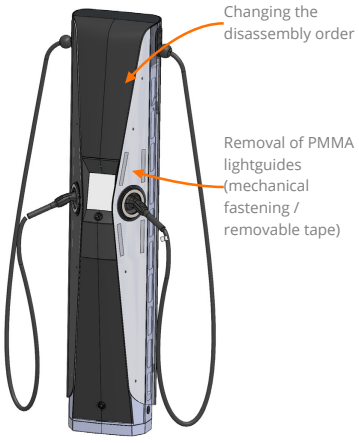
'EVBox Iqon_EU_01-JUN-2021_Simplified'

Redesign directions



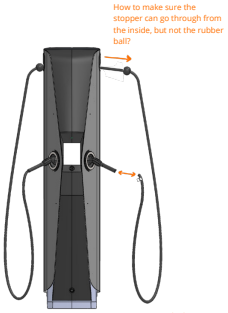
Charger cables

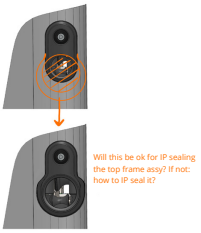
Installerbox (kWh-meter)



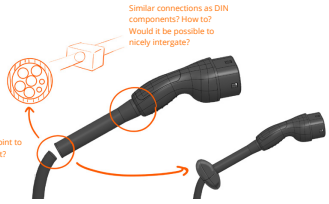
Side panels

Charger cables

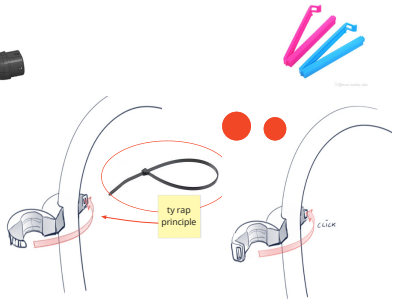


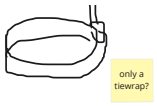


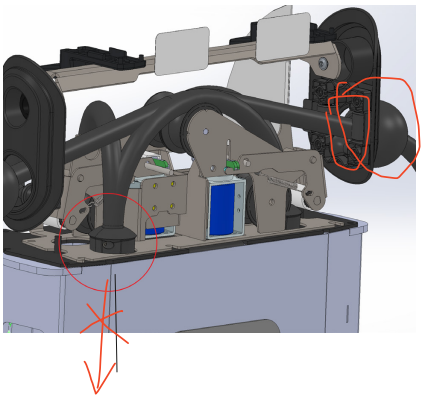
How to get the charger cables out of the frame without or with less unfastening activities?

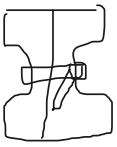


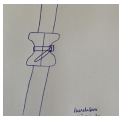
How to make a modular cable design?

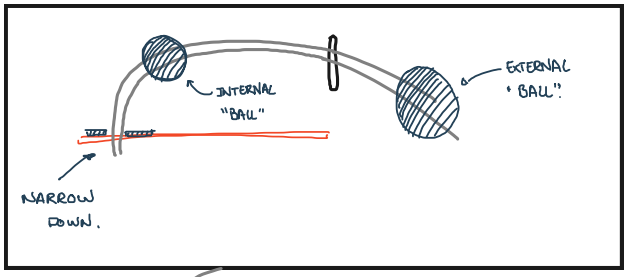


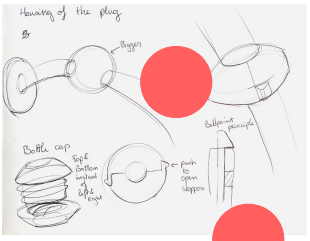


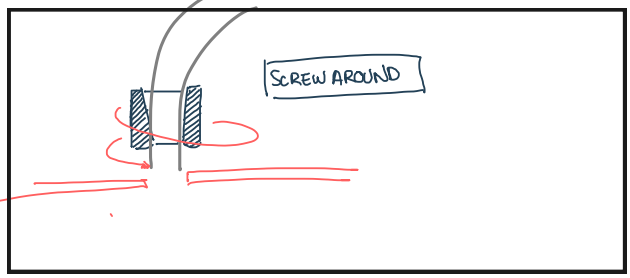


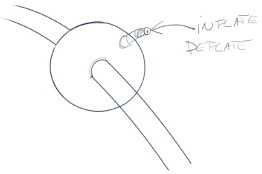


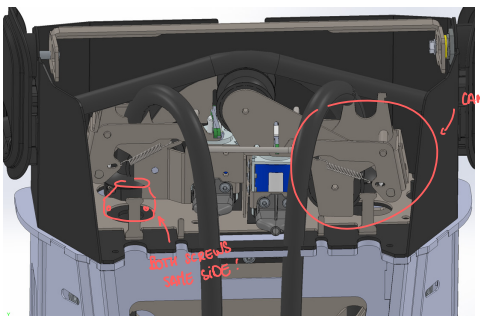




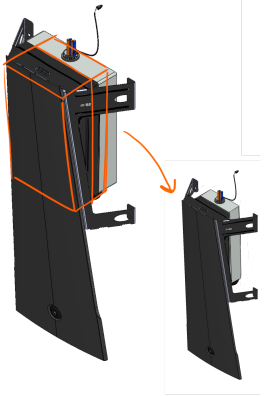








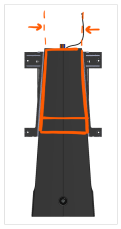
Installerbox



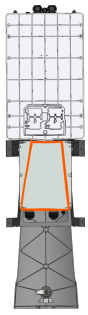
In case it becomes a large injection moulded Makrolon part:

- Can it be injection moulded? (multi-plate mould? Draft angle?
- Is it strong enough to serve as frame to attach the panels to?

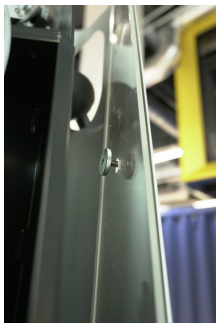
How to make the IB fit in between the side panels?

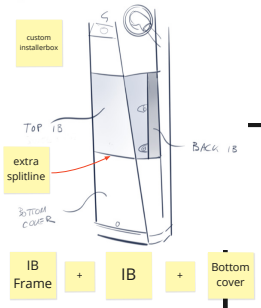


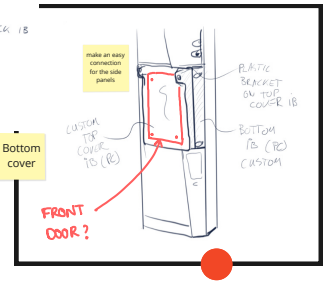
How to make up for the decrease in width? Increase height?

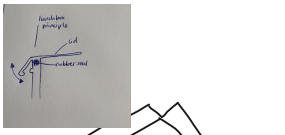


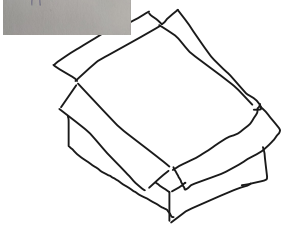
How to combine the IB cover, IB frame and bottom cover? Or only two of those?

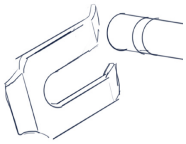


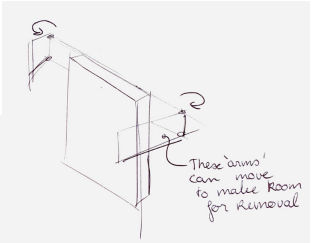


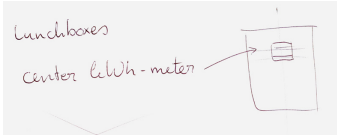


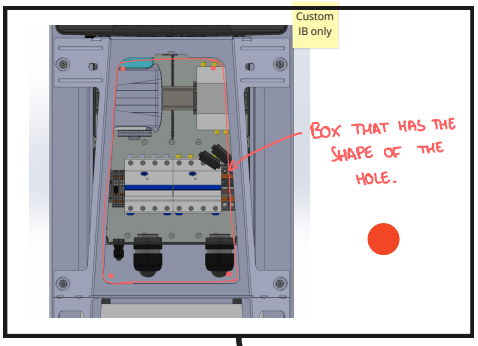


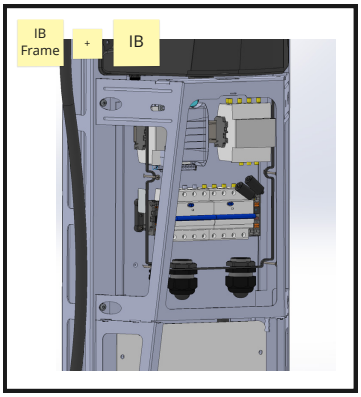


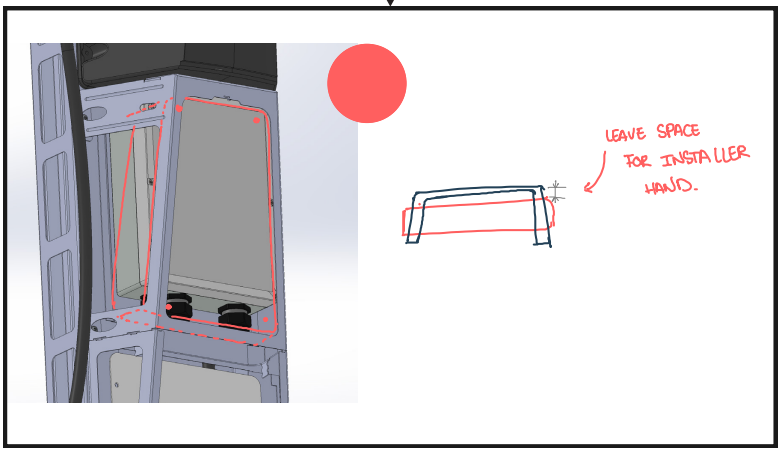






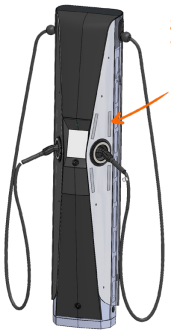


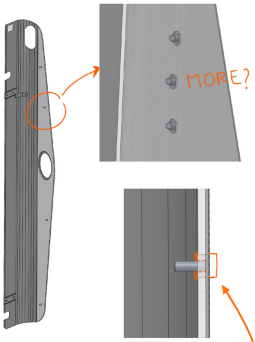




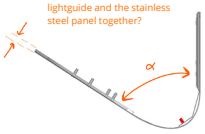
Side panels

How to fasten PMMA light guide to the side panels without tape?





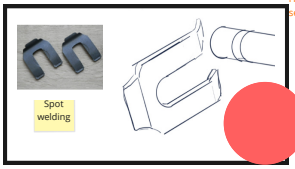
How to clamp the PMMA lightguide and the stainless steel panel together?

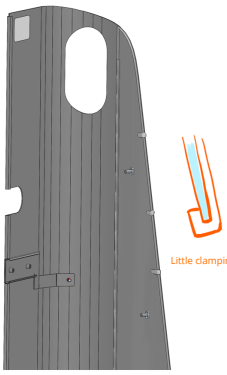


How to keep the tolerances as they are now?

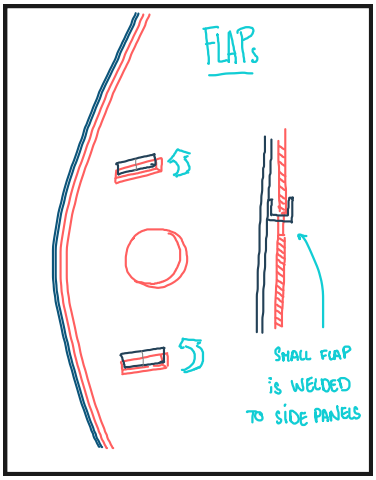
How bad is it to be able to see screws on the outside?

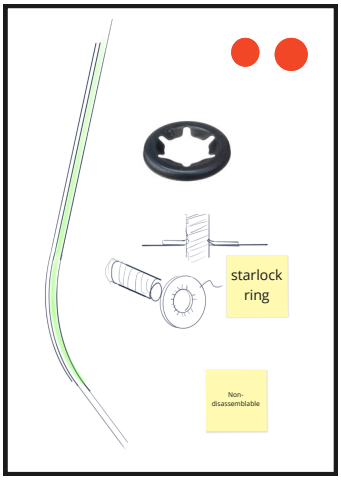
😱

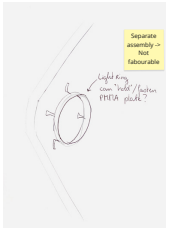




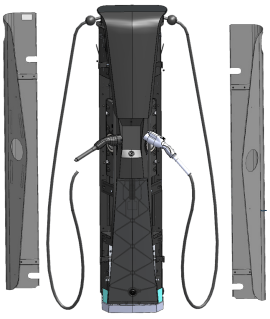
Little clamping hooks

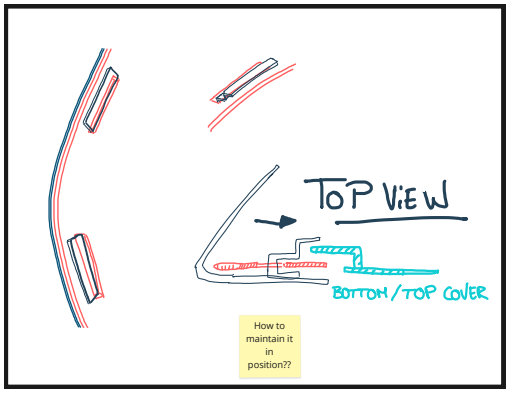


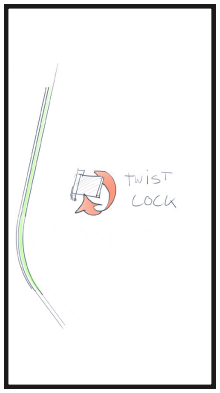


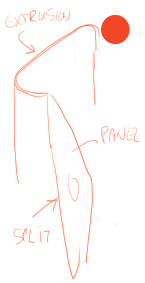


How to start disassembly with the side panels?









E. Installerbox specifications

Elektrische eigenschappen

Beschermingsklasse UL	12
Doorslagspanning AC	690 V
Doorslagspanning DC	1000 V
Beschermingsgraad	IP66/IP67
Beschermingsklasse	II

Materiaal eigenschappen

Geschikt voor buiteninstallatie	ja
Ontvlambaarheidsklasse volgens UL94	V2
Gloeidraadbestendigheid volgens EN 60695-2-11	850 °C
Halogeenvrij	ja
Industrie kwaliteit	ja

Omgevingscondities

Max. relatieve luchtvochtigheid 25°C	95 %
Max. relatieve luchtvochtigheid 40 °C	50 %
Omgevingstemperatuur min.	-35 °C
Omgevingstemperatuur max.	80 °C
Omgevingstemperatuur 24 uur	60 °C

Certificaten

Klasse	Door DLG bevestigde ammoniak bestendigheid conform DLG-testprotocol
Klasse	UL UL (50 & CSA 22.2 No. 94.1-07, UL 50E & CSA C22.2 No. 94.2-07)

Kleuren

Kleur onderbak	grijs
Kleur deksel	transparant

Afmetingen

Breedte	302 mm
Lengte	232 mm
Hoogte	90 mm

Mechanische eigenschappen

Bevestigingstype	Wand-/plafondmontage
Koppelbaar	ja
Type bovendeel	Deksel
slagvastheid	IK08

Materiaal

Materiaal onderbak	Polycarbonaat
Materiaal deksel	Polycarbonaat
Materiaal afdichting	Polyurethaan
Materiaal dekselschroef	Roestvrij staal V2A

Current installerbox specifications which have to be met in the redesign, (Spelsberg, 2021).

F. Off-the-shelf enclosure research