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Master thesis



# Sustainable material research

From Panel to Product

# Colophon

## Master thesis

MSc. Integrated Product Design  
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# Preface

During these last six months, I have been surrounded by the scent of coffee more than ever before. Now, that fact might not seem all that surprising, given the high average of Dutch coffee consumption: 2.4 cups a day (Bernard, 2020). Besides, it is common for students to comfort themselves with daily caffeine kicks from coffee, especially while working on their thesis. However, the coffee scent I am talking about is not linked to my own coffee intake but to the topic of my thesis. This, as my project is commissioned by material- and product manufacturer CoffeeBased, who uses coffee waste as their ingredient, and therefore providing coffee scented materials and products.

CoffeeBased has offered me an interesting case to work on, in which I could combine my interest in sustainability, love for design and curiosity for materials. The company employees have been welcoming and supportive, for which I want to express my gratitude. I hope to repay their guide with my designs and achieved insights. My TU Delft super(visory) team: Martien and JC, have also offered great assistance in project management and execution, alongside the much-appreciated mental support. Many thanks for your time and guidance!

Unfortunately, the COVID-19 pandemic cannot be left unmentioned, as the restrictions that followed impacted the execution of the project. For instance, the casual chitchat with students was severely restricted as the faculty was forced to reduce its visitor capacity. As much

as I took this for granted before, I now recognize the added value of these dialogues. Therefore, I want to say thanks to the (former) IDE students Jerry, Resy, Lotte and Nina for their coffee breaks, interest and check-ups, it was very much appreciated. Coincidentally, corona treatments played a big role in my research on material compatibility. Where the corona treatment for the pandemic urges people to stay 1.5m apart, I focused on corona surface treatments that help facilitate connections.

I also wish to take this opportunity to express how kind and supportive my housemates and family have been. At times, the experienced stress took its toll on my mood. Thank you for your patience. I wish to thank one last person, by means of the following suitable fact: *“The production of plastics was originally inspired by naturally occurring plastics, such as amber”* (Falabella, 2016). My sister, whose name fittingly is Amber, has been the one to inspire me to keep finding ways to persevere during these last few weeks.

And finally, thank you reader, for taking the time to read the thesis I wrote to finish my Master of Integrated Product Design! I hope the report provides what you’re looking for.

Get comfortable, grab a cup of coffee and (I hope you) enjoy the read!

Indy Vester  
Rotterdam, March 18th, 2021







# Executive Summary

Plastics that originate from renewable sources, such as potatoes or fungi, are called biobased plastics. Because of their origin, biobased plastics pose as sustainable alternative to traditional plastics, which are made from oil, a fossil substance. CoffeeBased is a small company that manufactures biobased plastic products, using their own developed materials (CB materials). To make these even more sustainable, CoffeeBased adds coffee waste as filler material to the biobased plastics. This reduces waste accumulation while generating a unique material. The coffee waste, called spent coffee grounds (SCG), adds attractive properties to the CB material. This includes a distinct coffee scent, and in combination with colorants, a coffee-like color is achieved. These unique properties suit the ambience of coffee product environments, like corporate coffee corners. CoffeeBased currently implements their CB material in (products such as) coffee machine fronts, coffee cups and coffee stations. The panels applied in the coffee stations are the most relevant to this thesis. The panel consists of a coating, adhesive, and a core that is laminated with CB material, referred to as CB laminate (EMPA, 2019).

Unfortunately, the CB laminate does not function properly in the desired user context, as it discolors and distorts. To prevent this impact from reducing its aesthetic appeal, optimization is required. Next to that, the sustainable character of the panel in its entirety is questionable, as the other components have not been analyzed on this characteristic. Therefore, the first design challenge is to find an integral solution to improve both the context resistance as the sustainable value. The second challenge is to design a condiment organizer, which could form the perfect occasion to test the proposed optimized panel. The function of the condiment organizer is to display and organize additives used in coffee machine beverages, called condiments. Next to the implementation of the panel, the design has to incorporate a form language that corresponds with other CoffeeBased products.

Based on the desires of the end user, limits of the manufacturing facilities and the resources available to

CoffeeBased, requirements were set. The sustainability requirements are set on incorporating more waste and more biobased materials whilst ensuring the emittance of volatile organic compounds (VOCs) remains low. Keeping these requirements in mind, alternatives to the current components of the panel were looked for in market research. The theoretical best components were chosen and (physically) tested, which were CB2 as laminate material, Resysta NoWood by FiberPlast as core, BioImpact by Canect as adhesive and the clear lacquer by BioPin as coating.

Four panel concepts are compared, each with different advantages. Increase in waste content is considered the most important optimization, as it suits the uniqueness of the CoffeeBased material. Therefore, the best suitable panel concept is the one composed of an EcoBoard core, CB1 laminate, BioImpact adhesive and BioPin lacquer. The optimized panel provides an increased sustainable value by a higher waste content of 83% and a biobased content increase of 12%, this while providing a potential VOC emittance reduction of 1%. Also, the concept entails edge band development, aiming to increase its aesthetic appeal and user context resistance.

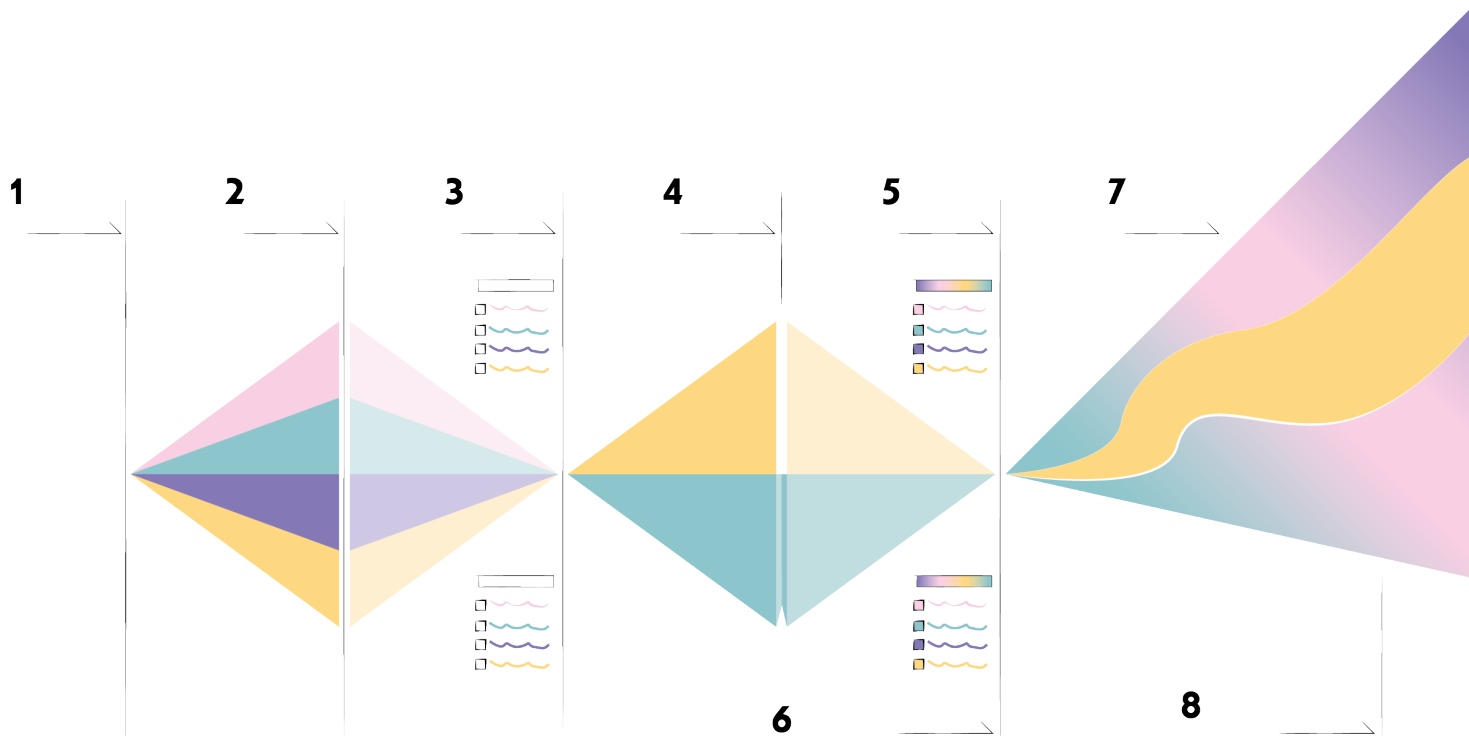
To tackle the second challenge, design ideas were generated based on the insights gained from brainstorm sessions. The four most promising ideas were presented to CoffeeBased, whose favorite was selected for further conceptualization. The final condiment organizer consists of a pre-assembled back frame, available with three, five or seven compartments. Condiment specific fronts can be selected by the user, based on their preference. Unfortunately, the necessary manufacturing method prevents the implementation of the optimized panel, thus a no-added formaldehyde plywood core is incorporated. Luckily, the aesthetic appearance does fit into the product portfolio of CoffeeBased, with its contour and surface engravements.

Therefore, this thesis project does not only provide CoffeeBased with valuable sustainable panel solutions, but also a new product design for their product portfolio.

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*Visualized chapter structure.*





## CHAPTER 1

# Project Overview

*This chapter introduces CoffeeBased, the client for this thesis, and the solution they provide for a useful and sustainable application of spent coffee grounds. In relation to this, the design brief for this thesis is formulated by firstly presenting the challenges and the report's structure after which the core principles are described.*

## 1.1 Introduction

The negative environmental impact caused by human behavior keeps becoming more apparent. Though global awareness is exhibited by the signatures on the Paris Agreement, action is needed to reduce climate change (United Nations, 2019). Relevant to this thesis are the solutions that product designers can offer. To ensure these are sustainable, three fundamental elements have to be taken into account: planetary health, human well-being and economic prosperity (Crul, Diehl & Ryan, 2009). To keep up with consumer demands, it is important to ensure sustainable performance of the products. Consumer preference has shifted towards preferring sustainable products over others, as 70% of the consumers have stated (Green Dot Bioplastics, 2020). The sustainable character of a product provides added value to the consumers, improving not only its sustainability but also its attractiveness to the market.

Material- and product manufacturer CoffeeBased tries to enact positive impact with their products, by using waste as base for their materials. As the name suggests, the waste that it harnesses comes from coffee consumption. For every cup of coffee, an average of 17.5 grams of spent coffee grounds (SCG) remains. The Dutch population alone accumulates approximately 300 million kilos of SCG annually. By means of current Dutch waste practices, this material ends up incinerated. Unfortunately, its high caffeine content makes it unsuitable for composting (CoffeeBased, 2020). CoffeeBased envisions a future where the remaining value of the SCG is harnessed instead of wasted.

To find viable solutions for transforming the low-valued SCG into high-value products, CoffeeBased employees have experimented and conducted thorough research. As a result, CoffeeBased has managed to produce their own bio-composite materials that can be used to produce plastic products. Bio-composites are composite materials characterized by their use of biobased plastics as matrix material. Biobased plastics distinguish themselves from traditional plastics as they are made using ingredients from renewable resources, like potatoes. In contrast, fossil-based plastic is made from a fossil substance: oil. There are several sustainable advantages of choosing biobased plastics over fossil-based ones, including its reliable supply source and

reduced environmental impact if incinerated (Šprajcar et al. 2012). As consumer's demand for bioplastics has been continuously rising for years, investing in this market also holds financial incentive (European Bioplastics, 2019). The CoffeeBased bio-composites are distinct by the SCG that is added as bulk material and will be referred to as: CB materials. To ensure a reliable supply chain, a coffee recycle system is initiated that retrieves SCG (in Dutch: Koffie Recycle Systeem, KRS). Registered large corporations with consistent high coffee consumption rates can dispose their SCG in special containers, regularly emptied by KRS parties (KRS, 2021).

The added SCG gives the CB material attractive properties that make it stand out from other bioplastics. These properties include a distinct coffee scent, and in combination with colorants, a coffee-like color. Together, these sensorial characteristics give the material a unique appearance, that matches the ambience of coffee corners. This is why CoffeeBased manufactures products that suit this user context, like coffee machine fronts, coffee cups and coffee corner furniture. The most relevant to this project are the panels that are used for the manufacturing of coffee stations. These panels exist of different components: a core, laminate, adhesive and coating. The laminates are made from the CB material, referred to as CB laminates. This adds sustainable value to the panel, as normally a fossil-based plastic laminate is used instead (EMPA, 2019).

CoffeeBased is continuously expanding and optimizing its material- and product portfolio. These material- and product developments can be initiated by CoffeeBased themselves, or by initiation of a third party. The ongoing collaboration with coffee (experience) supplier MAAS, is an example that has led to the production of coffee machine fronts and the mentioned laminated furniture panels (figure 1). Requested as part of this thesis project is the development of a condiment organizer design. Its function is to display and organize the additives used for all beverages provided by coffee machines. Together with the coffee cups, CoffeeBased is managing to slowly replace all plastic products present in the user context: the coffee corner.



*Figure 1. CoffeeBased coffee products: coffee cup (left), coffee machine front (middle) and laminated furniture panel (right).*

## 1.2 Design Brief

For this thesis, two interrelated challenges are selected whose results are aimed to benefit CoffeeBased. A short description of both challenges is given including the general approach of this project.

The **first** challenge concerns the panels that are laminated with the CB laminates. The panels are aimed to hold aesthetic and sustainable value. Currently, the aesthetic value is at risk when the panels are used in their desired user context, as it leads to discoloration and distortion. It requires better resistance against the sources of impact: heat, water, cleaning chemicals, sharp objects and UV radiation. The justified sustainable value of the panel is currently limited to its choice of laminate. As the other components have not been deliberately selected by their sustainable character. Thus, an analysis should be done to pinpoint what aspects of the panel require optimization in order to achieve a panel that holds more sustainable value. Therefore, the first challenge is to find an integral solution of a panel concept that integrates both these aspects: ‘optimize the sustainable value and context resistance of the panel’.

To get more familiar with the topic, the context is analyzed, including the involved stakeholders, implemented components, contribution to the market and sustainable optimization options (chapter 2). Based on the analysis insights, it can be determined what specific requirements are to be met and how their

achievements will be measured (chapter 3). Next, a market exploration will be conducted in order to select, assess and decide which components are most promising as replacement (chapter 4). Combinations of promising components will be made, providing panel concepts, each suitable for users with a different (sustainable) priority (chapter 5).

The **second** design challenge is to design a condiment organizer for coffee corner use (chapter 6). Its aesthetics need to correspond with the existing coffee products produced by CoffeeBased, specifically the coffee machine fronts and coffee station. It is aimed to mainly use the optimized panel to build the product, guaranteeing sustainable value and aesthetic resemblance to the coffee station. The generated ideas will be converged to main idea directions, which can be assessed. The most promising idea will be conceptualized with the aim to produce a functional prototype.

To what extent these challenges are tackled, will be discussed, leading to final recommendations for CoffeeBased (chapter 7). Finally, an evaluation to assess the project approach as well as personal development will be conducted (chapter 8). All-in-all, the project conducts sustainable material research, aiming to optimize CoffeeBased panels which can be used in a condiment organizer design (figure 2).

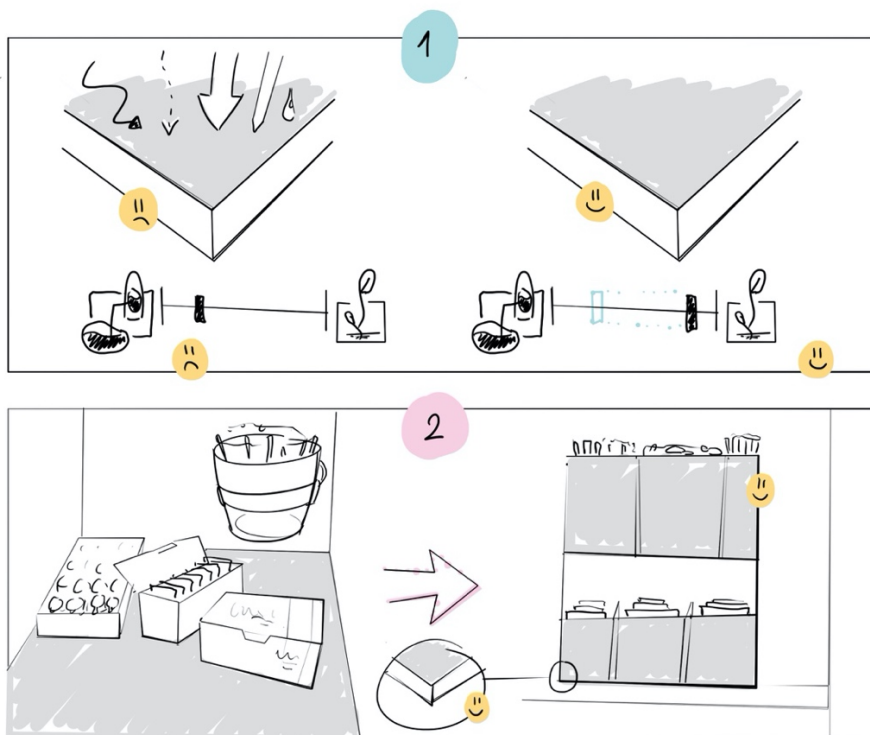


Figure 2. Project challenge 1 “optimize panel” (top) and project challenge 2 “design condiment organizer” (bottom).



### Reading guide

To ensure all design aspects are taken into account, three core principles are recommended to implement during design processes: end user and client desirability [D], technical feasibility [F] and economic viability [V] (Delft Design Guide, 2020). As this thesis is oriented around sustainable improvements, a fourth principle is added; sustainability [S]. These four core principles will

help structure analysis insights and its visual representations will help guide the reader through the report (figure 3).

Client and user desirability	[D]	Required/wished
Technical feasibility	[F]	Operational strengths
Economic viability	[V]	Profitability
Sustainability	[S]	People, planet, profit [V]

Figure 3. The core principles within this project and their references.



## CHAPTER 2

# Context

*In this chapter the four core principles are put into context for this project. The first section describes the desirability, looking into the needs of the most relevant stakeholders. Next, the technical feasibility of the panel is described, including its components and their compatibility. Hereafter, the contribution to the market of the CB laminate and the panel is described. Lastly, it is explained what sustainability aspects will be focused on during this project. The main insights from these sections are used to define the project challenges, set the requirements and pick suitable test methods.*



## 2.1 Stakeholders

*Client and user desirability*

CoffeeBased starts new material- and product developments by their own initiation or upon request by third parties, like MAAS. Their developments depend on the input provided by the coffee recycle service; wherein corporate employees provide SCG in exchange for store credit. In turn, this can be exchanged for products made from the SCG. As CoffeeBased does not have in-house production facilities, all their production is outsourced, expanding the web of stakeholders (figure 4). The most important stakeholders for the purpose of this thesis are the end users (corporate employees) and client (CoffeeBased), because their stakes are the highest. The expressed wishes of MAAS are taken into account and used as input for the ideation process, but not set as requirements. Although exlaimed wishes by production facilities are excluded, the manufacturing limitations and opportunities are kept in mind.

### CoffeeBased

CoffeeBased desires their multipurpose furniture panel covered by CB laminate to be more sustainable. Its sustainable value is currently limited to that of the CB laminate and its local production cycle. This, as all other components have not been deliberately chosen based on their sustainable performance. Therefore, CoffeeBased has expressed their wishes to have the

other existing components evaluated on their environmental friendliness and to consider replacements. To align with the sustainable character of the CB laminate, use of waste materials and prevention of fossil-based plastics is to be considered.

Unfortunately, the CB laminate does not comply with laminate standards on its own, as it easily discolors and distorts during production and use. To prevent reduction of its aesthetic appeal, a coating is added for protection. However, the use of a coating does not seem to solve all problems. For example, discoloration can happen before the coating is applied, via physical impact during transport (figure 5). As all production steps are out-sources and not limited to one facility, transport cannot be avoided. Also, the applied coating can alter the perceived color and prevent the user from tactile interaction with the texture on the CB laminate. Luckily, the distortion caused by impact during use, could be reduced with the applied coating. However, if not enough pressure is applied during the curation of the adhesive, the CB laminate can warp, reducing the panel's usability (figure 6). Both discoloration and distortion have negative impact on the aesthetic appeal, which should be avoided.

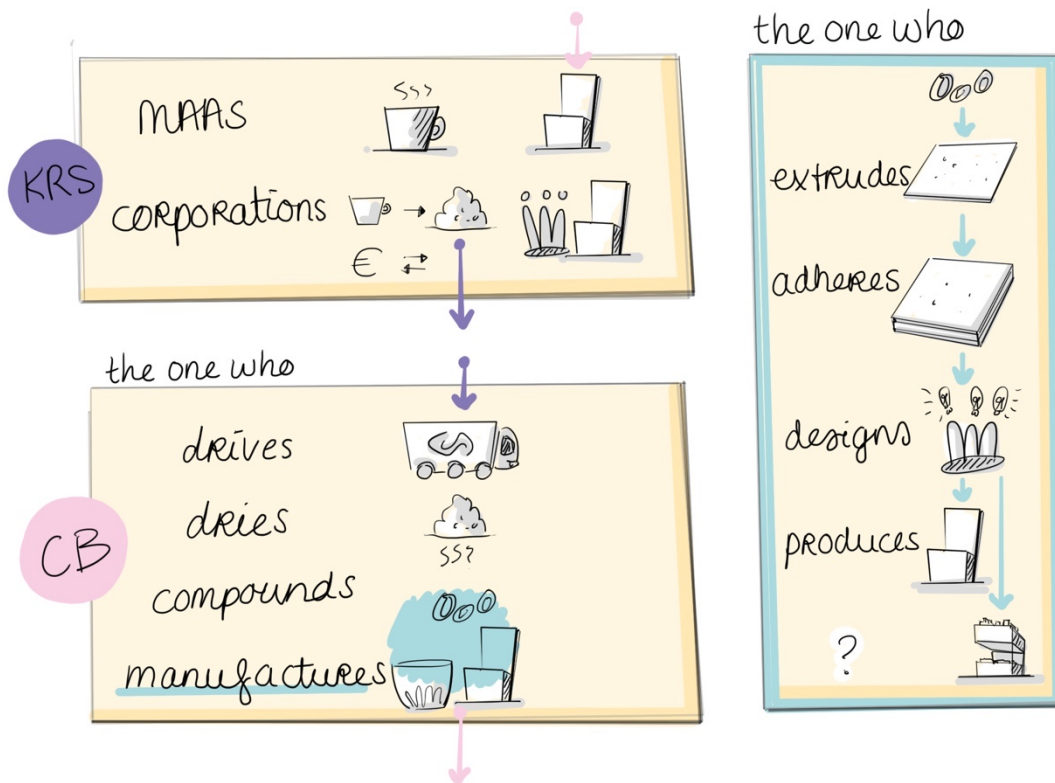


Figure 4. The stakeholders mapped to visualize the complexity of the outsourced production.



Figure 5. Physical discoloration caused by sharp objects during distribution.

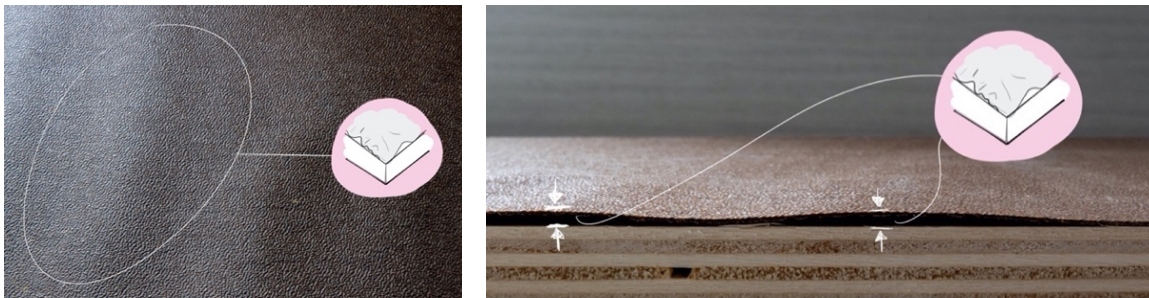


Figure 6. Distortions most likely caused by insufficient pressure during the curing process of the adhesive.

CoffeeBased is asked by collaborator MAAS to develop a condiment organizer using the optimized panels. The product is aimed to be sold alongside the other coffee products: coffee machine front, coffee cups and coffee station. The condiment organizer should be low-cost, as initially only a small batch is to be manufactured. Further requirements concern its basic function, which is to orient and display a variety of condiments. The most popular condiments are tea bags, stirring sticks, milk

cups and sugar sachets (figure 7). Depending on the specific coffee machine model, the corresponding condiments that are requested differ. Therefore, it's required that the design takes this flexibility into account with a modular system. Next to the implementation of the panel, the design has to incorporate a form language that corresponds with that of the other coffee products. (figure 8).



Figure 7. The most popular condiments from left to right: stirring sticks, milk cups, sugar sachets and tea bags.



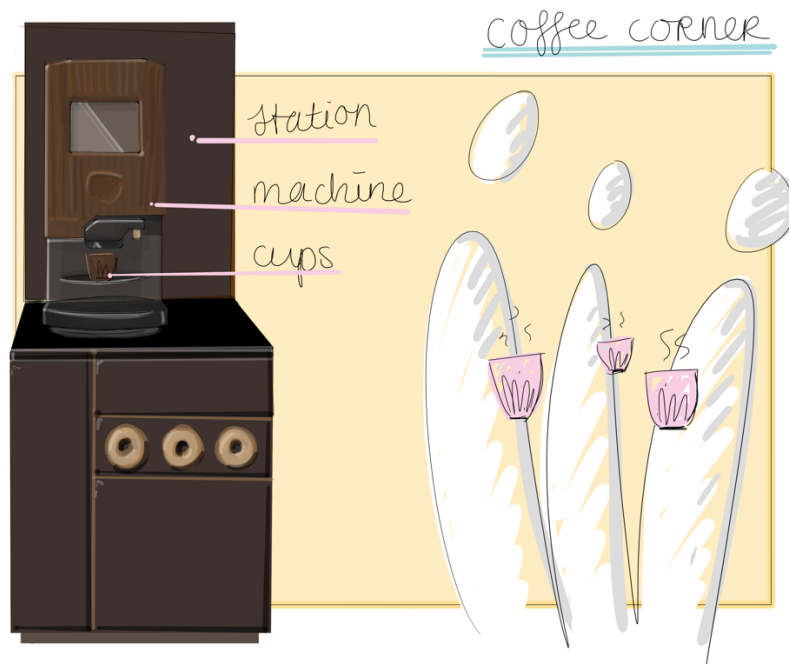


Figure 8. The coffee corner including coffee station, coffee machine with the coffee machine fronts and coffee cups.

### Corporate employees

The imagined end users of both the panel and condiment organizer are corporate employees. Currently, the panels are aimed to build coffee stations used in corporate offices. As corporate employees meet (potential) clients in these gathering places, its appearance is considered important as it represents the corporations. The CB laminate plays the biggest part in the panel's appearance, including its sensorial properties: smell, color and surface texture. Besides the standard preference for aesthetically appealing products, it also helps advertise that the corporation makes sustainably conscious purchase decisions. To enhance the communication of this message, additional texts or figures should be added to the exterior advertising its sustainable value. The color contrast between the message and its adjacent background should be big enough to also be accessible to people with poor eyesight (WRC, 2010). As the CB laminate has a high price and most of its value is in its sensorial properties, it is considered sufficient to only cover the exterior of the product.

When in use, there are certain factors that have impact on the durability of the products which need to be considered. Hot beverages served in the coffee corner can have an undesired impact because of the conductive heat via the cups [between 2 physical objects] or the direct convective heat caused by spills [via a fluid motion] (Ashby et al., 2014). Also, products used for regular cleaning of the station might contain chemicals and abrasive particles. Lastly, even though the coffee stations are located indoors, they might still be exposed to a considerable amount of UV radiation from sunlight, depending on their location within the office (FSEC, 2014). These factors negatively influence the CoffeeBased laminate that currently covers the panel. As the condiment organizer is aimed to be made from these panels, both would be exposed to these sources of impact and are in need of protection (figure 9). It has not been analyzed thus far if the application of a coating suffices to prevent the undesired lighter and darker discoloration and/or distortion. To illustrate the distortion and discoloration, the CB laminate is put in the coffee corner of a domestic environment (figure 10; figure 11; figure 12). Any chemical discoloration that may be caused by the dyes inside the CB materials are left out of scope.

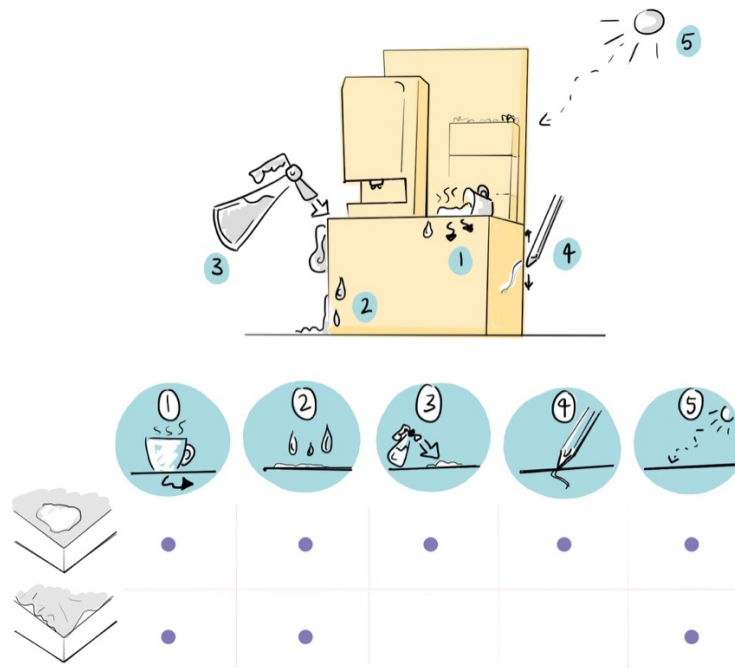


Figure 9. Sources of impact: (1) heat, (2) water, (3) cleaning chemicals, (4) sharp objects and (5) UV radiation.



Figure 10. Impact on the CB1 laminate caused by 8 days in the coffee corner of my own home.



Figure 11. CB1 laminate discoloration caused by coffee corner use in the displayed situation in figure 10 for 39 days.

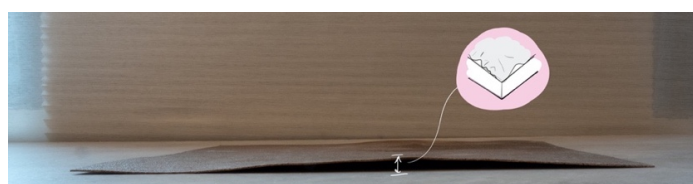


Figure 12. CB1 laminate distortion caused by coffee corner use in the displayed situation in figure 10 for 39 days.



## 2.2 Components

### Technical feasibility

#### The panel

To provide design freedom to the furniture designers, it is mandatory that the panel sustains common industrial processing and is delivered in the standard size of 1.22 times 2.44 meters with a thickness close to 18mm. The panel should support size adjustment by CNC milling as well as common types of mechanical fastening, like screws. Large forces are expected to be applied, which are commonly covered by the mechanical properties of the core. Traditional core materials include medium density fiberboards (MDF), oriented strand boards (OSB), particleboards and plywood (Precision Veneer, 2020). As these have proven itself worthy as furniture core material, their mechanical properties are used to set the performance criteria: a stiffness of 1800 MPa and a tensile strength of 8500 MPa (CES Edupack, 2019). For the panels in the condiment organizer, less mechanical strength is required. Therefore, two cores are selected, a thicker one for general furniture implementation and a thinner one for specific application in the condiment organizer. Because similar context scenarios are

expected, both panels have to provide the same resistance against the before mentioned sources of impact (figure 13). The proposed production plan should be limited to the machines offered by a singular production facility, preferably the facilities at hand. Else, the partially produced product needs to be transported, increasing transportation costs and use of energy, adding another stakeholder to the list.

The panel is not made out of CB material entirely because of its high price and low mechanical properties. Therefore, other components are required, labelling it a composite panel (table 1; figure 14). To function as one solid composite material, all components need to be fixated to its adjacent layers. The effectiveness of this joint depends on the compatibility between the liquids and the solids. The liquids consist of the coating and adhesives, whereas the solids refer to the core and laminate. The liquids need to be spread across the surface of the solids while in liquid state, in order to create a fixed solid composite when solidified.

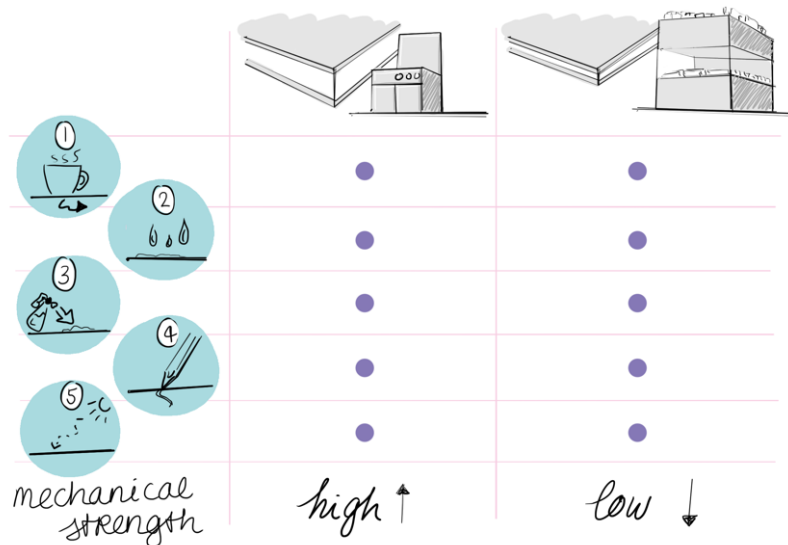


Figure 13. The impact resistance factors and mechanical strength requirements for: panel and condiment organizer.

Nr	Type	State	Material	Amounts
[ 1 ]	Coating	Liquid	Polyurethane alkyd resin (PU resin)	2
[ 2 ]	Laminate	Solid	CB material	2
[ 3 ]	Adhesive	Liquid	Polyurethane hotmelt (PU hotmelt)	2
[ 4 ]	Core	Solid	9 plies of poplar plywood including 8 layers of adhesive	1
<b>Total</b>	<b>Panel</b>		<b>Composite</b>	<b>1</b>

Table 1. Bill of materials of current panel.

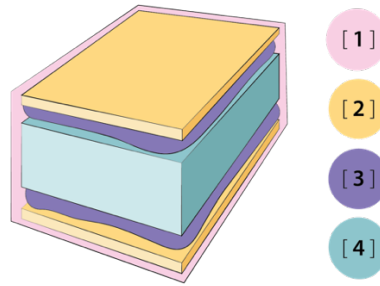


Figure 14. The components of the panel including the numbers used in table 1.

### CB laminate

Traditional laminates provide protection and aesthetic appeal by means of a formaldehyde-melamine resin and printed paper respectively (figure 15; Centrum Hout, 2019). As previously stated, the CB laminate does not offer the chemical resistance needed to protect the inner materials in the desired user context, requesting the need for a coating. With its remaining aesthetic value, the CB laminate functions as replacement of the printed paper, whereas the coating replaces the resin. To validate the panel as sustainable alternative, either the coating needs to be sustainable, or another CB material needs to be used.

Such material development is already taking place, wherein another CB material is considered for the

laminate. For clarity reasons, the CB material currently used is referred to as CB1 and the to-be-produced alternative as CB2 (table 2). Both materials are made from SCG added to a bio-composite matrix. The difference lies in the origin of the biobased plastic used inside the bio-composite. In CB1 the biobased plastic originates from starch polymers derived from waste potato peels, which are plasticized to obtain thermoplastic properties. For CB2 monomers from sugarcane are extracted and synthetically altered to achieve a plastic that is chemically identical to fossil-based polyethylene, a polyolefin. Advantageously, the CB2 material is expected to have better chemical resistance against heat, water and cleaning chemicals as it is dishwasher proof.

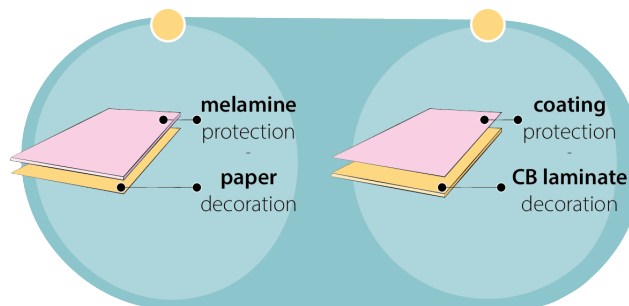


Figure 15. Layers inside traditional laminate (left) and the CB laminate + coating (right).













		CB1	CB2
<b>Compatibility</b>	Adherable	 >20 dyne/cm	 Expected: 31-36 dyne/cm
	<b>Impact from</b>		
	1. Heat		
	2. Water		
	3. Chemicals		
	4. Sharp objects		 Unknown
	5. UV radiation		 Might make it sticky
<b>Aesthetic appeal</b>	Color	Light brown	Dark brown, white powder
	<b>Conclusion</b>	<b>Needs protection</b>	<b>Needs experimentation</b>

Table 2. Most important material properties of the CB1 and CB2 materials.

**Liquid to solid compatibility**

Materials can be categorized as polar or non-polar. Polarity describes the permanent distribution of electrons inside the molecules. Unequal distribution leads to a division of the molecule into a positive and negative part. The positive part attracts to the negative part of other molecules or substances, and vice versa (inter-molecular bonds). The amount of bonds that can be formed depends on the atoms in the molecule. And the more unequal the distribution, the more polar the material (López-García, 2019).

The molecules inside a uniform polar material are attracted by their adjacent molecules, creating pull from all sides. However, the outer molecules on the surface do not have as many neighboring molecules and as result: there is more pull inwards, creating tension (figure 16). For solids this is called their surface free energy, and for liquids it is referred to as their surface tension (Johansson, 2017). Non-polar materials do not have the permanent positive and negative parts that attract with

their polar bonds. However, all substances, including polar substances, form temporary dispersive bonds (figure 17). This, because the electrons in molecules move, causing temporary positive and negative areas.

All matter desires to be in a state that requires the least effort, creates the least tension. Since the surface molecules and their lack of bonds is what causes the tension in polar materials, it is desired to have as little of it as possible. Consequently, solids have a lower surface free energy when their surfaces are covered. Liquids desire to stay in droplet shape, as this creates the least surface area. Inconvenient, as the surface free energy of the solid needs to be stronger than the surface tension of any applied liquid, for the surface to be covered. This is called wetting the surface. The less difference in tension, the more equal the polarity. Also, the more similar their permanent polar bonds [P] to temporary dispersive bonds [D] distribution leading to a smaller contact angle (figure 18).

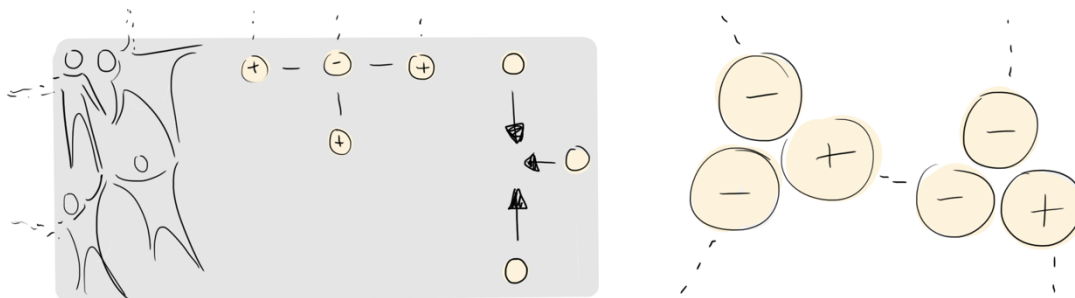


Figure 16. Polar surface molecules represented as persons, with their arms and legs representing the molecular bonds [P], creating a net inward tension

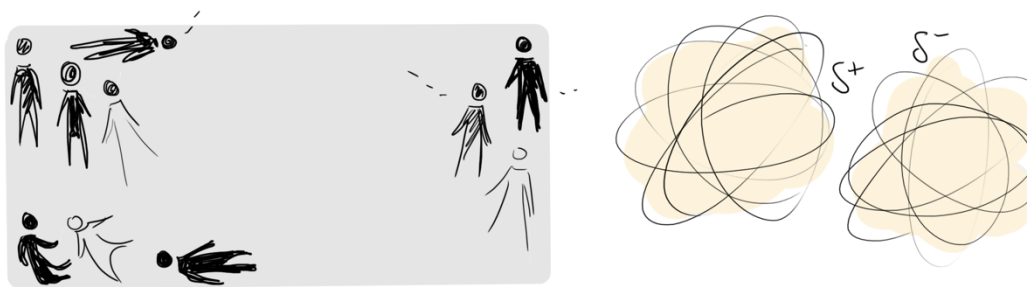


Figure 17. The dispersive bonds [D] creating temporary attraction of all molecules (right).

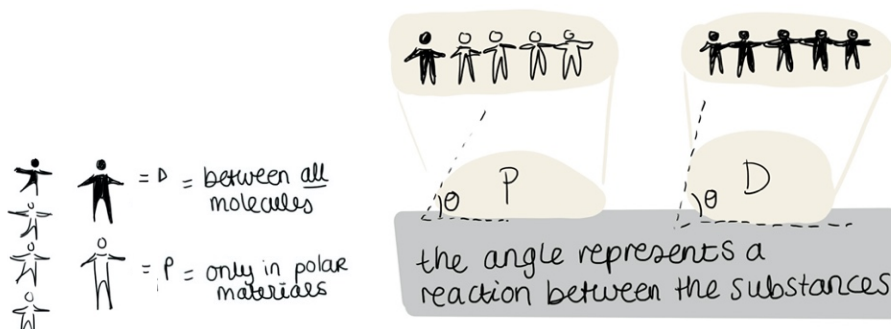


Figure 18. A surface with a polar droplet [P; left] and a dispersive droplet [D; right].



In the case of the panel, both the adhesive as the coating is required to wet the surface. Therefore, these liquids have to have a lower surface tension than the surface free energy of the adjacent solids: the CB1 laminate and/or core material (figure 19). The core, adhesives and coatings will be bought off the market, making the assumption that their properties are suitable for adhesion. The same assumption cannot be made for the CB materials, as they are manufactured by CoffeeBased themselves.

The CB materials contain SCG, which consists of about 7-15% oil, a non-polar substance (Karmee, 2017). The more non-polar the material, the lower the tension. Thus, the less likely that the surface free energy is high

enough for wetting. Because the CB1 has been adhered with the PU hotmelt, its surface free energy is assumed at least higher than that of PU hotmelt. The CB2 material is based on a biobased plastic that is a polyolefin, a non-polar material (Surface tension, n.d.). This fact indicates a low surface free energy can be expected, which is why a test needs to be done to see if it could function as laminate. If the surface free energy of the CB2 material is too low, it can be (temporarily) increased by surface treatments or primers. Surface treatments change the surface properties of materials, by 'charging' them, creating temporary polar groups on the surface. In the timeframe that the surface free energy is increased, the material should be adhered (Tod, Atkins & Shaw, 1992; Krüss, n.d.; Ellsworth Adhesives, 2018).

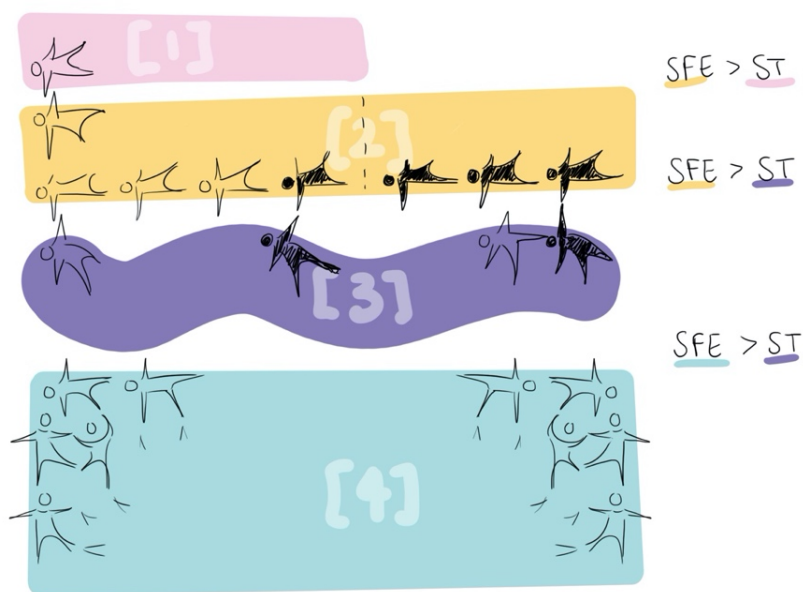


Figure 19. The panel components and their surface free energy (SFE) and surface tension (ST) of the liquids.

## 2.3 Market

### *Economic viability*

#### **Value added to SCG**

CoffeeBased adds value to waste materials, SCG, by transforming it into an ingredient suitable for high-value product manufacturing (figure 20; figure 21). Specifically, the drying of the SCG adds the most value as it transitions the waste into a viable filler option to be used inside a bio-composite matrix. Retrieving the SCG is made cost effective as corporates have to pay for it to be retrieved, which is turn awards them with a discount on the purchase of CB products. Bio-composite are more expensive than fossil-based plastics (Goldsberry, 2020). Adding dried SCG makes it even more expensive. The aesthetic and sustainable value should therefore make the higher price worthwhile.

#### **Market potential**

Currently, it is not recommended to sell the CB laminate on its own. This, as it is in need of protection and thus does not suffice as laminate by itself. In the panel, this shortcoming is accepted as the addition of coatings is common. CoffeeBased is relatively new in the furniture panel market and its CB laminate is fairly innovative for the branch. The first step is to ensure that the panel functions properly, and it suits the needs of potential end users. Thereafter, more innovative components can be considered, like recycled plastic. For now, the Panel is unique because of the CB laminate, and after optimization it can be presented as a sustainable alternative to traditional furniture panels.

The panels have an aimed retail price of €150 per standard panel (1.22x2.44 m), depending on the requested production volume (Addink, 2020). The sum of all material costs has to be €50 to make this a viable product development for CoffeeBased and all

stakeholders involved. To limit overspending, it is recommended to only buy as much material as needed for a first batch. Costs for machine equipment can be minimized by selecting the manufacturing facilities accordingly.

Like the other CB products, the condiment organizer can be sold by the company MAAS. The condiment organizer would be added to their current inventory to enhance the coffee experience they try to convey. By using the coffee recycle service discount, CoffeeBased urges the corporates that deliver the SCG to also purchase the products. As the product is aimed to be produced in small batches, large investment risks can be avoided in case the product does not catch on. Market research indicates that normal condiment organizers have purchase prices varying between €20 and €135 (Restaurant-ware, 2020). The estimated price for the material costs is aimed to be between €7 and €45. This estimation implements the same purchase-to-production-ratio as was indicated for the panel.

#### **Stakeholder value**

As CoffeeBased is a small-sized company, the names of all contributing facilities are not broadcasted. This, to maintain ownership of the production processes and prevent competitors' advantage. As a consequence, the oftentimes medium sized contributing facilities are not given due public credit for their input. The prevention of waste accumulation and reduction of need for fossil-based plastics, will eventually play a small part in the alleviation of negative environmental impact. As such, societal costs associated with the environmental pollution can be prevented.



*Figure 20. Low value SCG retrieved by the coffee recycle service.*



*Figure 21. High value CB material used to produce CB products.*

## 2.4 Sustainability

### Sustainability

Sustainable innovation is based on the following 3 drivers: planetary health, human well-being and economic prosperity. For this project, the focus is on the planetary health drivers because this is where the biggest potential positive yield is expected (Crul, Diehl & Ryan, 2009). As for the human well-being, CoffeeBased already focusses on local producibility and provides employment to otherwise unemployed minority groups. This, when assembly, storage or distribution is needed. Lastly, economic prosperity is covered in section 2.3.

The EcoDesign Strategy Wheel describes how designers can alleviate environmental impact during all lifecycle stages of a product's lifetime. Most relevant for the panel are the three stages of extraction, use and disposal. Because the panels are sold to other parties who use them for building furniture, the production and distribution are left out of the scope. In all stages, the material selection plays the most prominent role. Currently, the panel is distinctive by its use of CB material instead of traditional melamine-formaldehyde resin laminates.

The first stage is extraction. The melamine-formaldehyde resins commonly used in furniture panels, require fossil fuels to be extracted. Fossil-based plastic is made from polymers extracted from oil; a fossil fuel that is made from biomass that lived millions of years ago. From the perspective of humans, the oil reserves are considered non-renewable, lacking the ability to provide

a secured supply (figure 22). In contrast, the CB laminate is based on SCG that are produced daily and bio-composites that are based on sources that can be renewed, like agricultural sources or fungi (Šprajcar, 2012). Using a renewable source helps prevent the fossil resources from becoming depleted, allowing future generations to also have access to these resources. Also, a more continuous supply is ensured (figure 23). Unfortunately, the coating and the adhesives inside the core of the panel also contain fossil-based plastics. The second stage is the use of the panels: in comparison to the traditional panels, this is likely to be similar. The only difference being the reduced functional lifetime caused by the shortcomings of the CB laminate. The last stage concerns the disposal. In the Netherlands, 80-100% of the time furniture panels end up incinerated, releasing carbon dioxide (CO<sub>2</sub>) (Nationale Milieu Database, 2020). Biomass captures CO<sub>2</sub> from the air and uses the carbon to build polymers to grow. Incineration breaks up the molecule bonds inside these polymers, releasing the CO<sub>2</sub> back into the atmosphere. Unfortunately, this means the carbon inside the fossil-fueled plastics that was captured millions of years ago, is released. In comparison, burned wood or biobased plastics releases CO<sub>2</sub> that was captured recently, relative to a human perspective (figure 24). If not incinerated, the environmental damage caused by unorganized waste overload can also have detrimental effects on the planet and its species (Šprajcar, 2012; Vinod, 2020).



Figure 22. Linear economy (left) and its consequence (right).

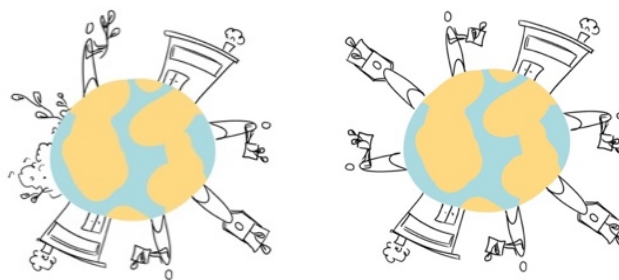


Figure 23. Circular economy based on bio-recycling (renewable resources and biodegradability) (left) and mechanical recycling (reusing or refurbishment) on the right.



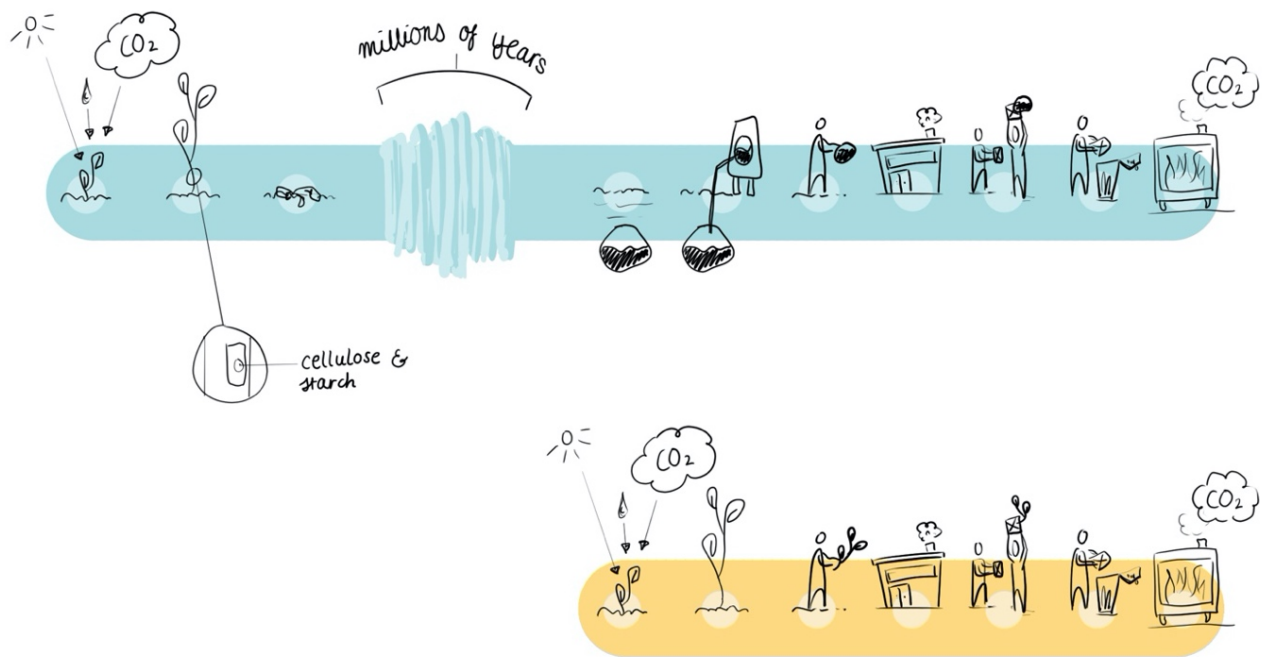


Figure 24. The comparison between releasing CO<sub>2</sub> that was captured millions of years ago and that which was released recently.

Several opportunities were thought of that could contribute to the panel’s sustainable optimization. The first consideration was utilizing CB1’s ability to biodegrade, by only selecting biodegradable components. Depending on the molecular structure, polymers can be recognized by enzymes in nature. Naturally, the enzymes break down the polymers into soil. Unfortunately, even if all optimized components are biodegradable, the biodegradable plastic from CB1 is not desired to be put into the compost bin by the Dutch waste management (Rijkswaterstaat, n.d.). Thereby, it’s only advantageous when discarded into nature, which is not likely to be the case for furniture panels nor condiment organizers. The second consideration was to set up a retrieval system, using the transportation network of the coffee recycle service. Once retrieved, the PU hotmelt adhesive can be reheated whereupon all components can be reused, refurbished or disposed of accordingly (Tempelman, Shercliff & Eyben, 2014; Adhesives(a), n.d.). This would suit the CoffeeBased mindset, to not be let materials that still hold value, go to waste. Also, this closed looped system would be an example of a circular economy including economic and ecological advantages (Products that last, 2015).

Unfortunately, these and more potential opportunities did not fit the panel’s requirement to suit the resources of CoffeeBased.

Considering the inevitable end-of-life scenario of the panel, it is decided to make sure the panel is ‘okay to burn’. Therefore, waste materials are aimed to be used as input, temporarily saving it from incineration by turning it into a high valued product once again. To aim for a minimal impact caused by inevitable incineration, these waste materials should not originate from fossil fuels. Regrettably, by excluding coatings and adhesives that use fossil-based plastics, volatile organic compounds (VOCs) are often used. VOCs are gasses that evaporate involuntarily. When exposed too much they can cause carcinogenic effects (Lenntech, n.d.). As the condiment organizer is to be made from the panels, the material optimization will ultimately add sustainable value to the condiment organizer sustainable as well. For each component of the current panel, the percentage of waste content, biobased content and its VOC emittance is determined, based on the thickness of the component relative to the entire panel (see table 3), for the entire calculation read Confidential Appendix A.

Nr	Component	Amount	Thickness	Part proportion	Waste content in component	Biobased content in component	VOCs
[1]	Coating [PU alkyd resin]	2x	0.5 mm <sup>1</sup>	4.8%	0%	0%	Unknown
[2]	Laminate [CB1]	2x	0.8 mm	7.6%	>20% <sup>5</sup>	Confidential	0
[3]	Adhesive [PU hotmelt]	2x	0.2 mm <sup>2</sup>	1.9%	0%	0%	0
[4.1]	Core plies [Poplar]	1x	16.4 mm	78%	0%	100%	0
[4.2]	Core adhesives [phenol formaldehyde resin] <sup>4</sup>	8x	0.2 mm <sup>2</sup>	7.6%	0%	0% <sup>3</sup>	7.6% Probably some
<b>Total panel</b>		<b>1x</b>	<b>21 mm</b>	<b>99.9%</b>	<b>1.5%</b>	<b>83.6%</b>	<b>7.6%</b>




Table 3. Content initial panel

<sup>1</sup> (BioHome(a), n.d.)

<sup>2</sup> (Purk, 2017)

<sup>3</sup> Potential water inside components have been left out of the calculation

<sup>4</sup> (Centrum Hout, 2019)

<sup>5</sup> Excluding the waste used inside the biobased plastics, due to unknown proportions.

### Higher waste content

Currently, the amount of waste reused in the panel is low, namely at 1.5%. The biggest increase is likely to be met by optimizing the core material as it holds the biggest panel portion. As plywood cannot be made from waste, an alternative has to be found. Also, quick market research on coatings and adhesives made from waste materials turned out blank. Therefore, it is assumed it is not currently sold on the market and is taken out of the comparison.

### Higher or maintain biobased content

Luckily, the percentage of biobased content is already quite high. If waste cannot be used for the core, biobased materials are preferred. If wood is used, a FSC certification is required. Sadly, binders in adhesives are often synthetical (Adhesives(a), n.d.). Whether components on the market are actually sustainable is quite difficult to tell due to greenwashing, as companies are not eager to promote ingredients that could be bad

for the environment. Also, terms like 'green', 'organic' and 'eco' might suggest the product to be more sustainable than they in reality are. Regulations and certifications aim to prevent this (Maiburg, n.d.).

### No added VOCs

If fossil-based plastics are replaced in coatings and adhesives, often solvents and other ingredients are added that could emit VOCs (Centrum Hout, 2019). The VOC-levels in products dictate the involuntary release of formaldehyde, terpenes, flame retardants and plasticizers into the air. Regulations in the Netherlands limit the allowed VOC-levels to 420 g/L in coatings, 30 g/L in primers and 150 g/L in adhesives (Europees Parlement en de Raad, 2004). Noteworthy is that not all VOCs are bad. For instance, formaldehyde naturally occurs inside wood, vegetables and can even be found inside our body. Ultimately, we do not want more VOCs than those we are already exposed to (Lenntech, n.d.).







## CHAPTER 3

# Project boundaries

*The insights of the analyzed context are used to specify what requirements should be met to reach the project challenges. Hereafter, the methods are described that are used to measure if these requirements are met.*

### 3.1 First challenge

Based on the insights gained from the context analysis, requirements are set to which the solutions for the content resistance and sustainable optimization are bound (table 4). Proposed solutions to enhance the context resistance also influences the sustainable performance and vice versa. This is why it is decided to look for market available alternatives at component level and not per optimization challenge.

To increase the context resistance, the CB1 material should be replaced or a more sustainable alternative to the current coating needs to be implemented. To test the viability of CB2 as laminate material, samples will need to be made first. Market research will indicate if there are also alternatives to the adhesive and core, that hold better sustainable values. Ideally, by having a higher waste content and a higher biobased content whilst avoiding VOC emittance.

Principle	Nr.	The panel ...	Laminate	Core	Adhesive	Coating	Primer/ treatment
Desirability	[D1]	... is applicable to multiple purposes, like furniture.	●	●	●	●	●
	[D2]	... does not distort during production or use, thus maintaining the surface texture.	●	●	●	●	●
	[D3]	... does not discolor during production or use, thus maintaining its coffee color.	●	●	●	●	●
	[D4]	... does lose its coffee smell.	●				
Feasibility	[F1]	... is suitable for traditional furniture panel manufacturing machines specifically CNC milling.	●	●	●	●	●
	[F2]	... abides mechanical alterations, like screws.	●	●	●	●	●
	[F3]	... is producible in standard size of 1.22 by 2.44 m.	●	●			●
	[F4]	... has a maximum tensile strength of 8.5 MPa.		●			
	[F5]	... has a minimum stiffness of 1800 MPa.		●			
	[F6]	... is usable right away to be efficient.		●			●
	[F7]	... does not require extra manufacturing facilities.	●	●	●	●	●
	[F8]	... has compatible components, thus the CB laminate should have a surface free energy of: minimally 38 dyne/cm (in general) minimally 73 dyne/cm (in case of a water-based adhesive/coating) minimally 68.4 to 79.9 dyne/cm (in case of a	●				

		phenol-formaldehyde adhesive/coating)					
		minimally 20 dyne/cm (in case of PU hotmelt adhesive)					
<b>Viability</b>	[V1]	... have reduced market risk, by only implementing components that can be bought off-the-shelf, ensuring market acceptance.		●	●	●	●
	[V2]	... not implement components that make the panel cost more than €50 in total.	●	●	●	●	●
<b>Sustainability</b>	[S1]	... has a higher waste content than 1.5% in the total panel.	● (out of scope)	●			
	[S2]	... has a higher biobased content than 83.6%.	●	●	●	●	●
	[S3]	... has lower chance of VOC emitting content than 7.6%; including production and use.		●	● < 150 g/L	● < 420 g/L	● < 30 g/L (primer)
	[S4]	... originates and allows producibility and assembly within Dutch borders.	●	●	●	●	●

Table 4. Requirements for the first project challenge visualized.

<sup>1</sup> (Surface tension, n.d.)

<sup>2</sup> (Hse, 1972)

<sup>3</sup> (Nottay & Rides, 2005)



## 3.2 Second challenge

The second project challenge focusses on designing a condiment organizer by utilizing the optimized panel. Meanwhile, its aesthetics is required to complement the existing CB coffee machine front and CB coffee station. Whether aesthetic resemblance is achieved will be determined by a checklist. Resemblance is defined as similar use of materials and its colors, communication

style and contour shapes. The sustainable value of the condiment organizer comes from its use of materials (see challenge 1) and its contribution to completing the CB coffee corner set. The more complete the set, the more materials can be saved, increasing its sustainable impact. All requirements for the condiment organizer design are described in table 5.

Principle	Nr.	The condiment organizer ...
Desirability	[D1]	... has the same form language as the coffee station and coffee machine fronts.
	[D2]	... is able to orient and display the following condiments: tea bags, stirring sticks, milk cups and sugar sachets.
	[D3]	... is flexible and allow for changes in condiment brand variations.
	[D4]	... contains visual communication to represent its sustainable character.
	[D5]	... is accessible to all types of users, including but not limited to left and right-handed users and users with poor eyesight.
Feasibility	[F1]	.. is manufacturable with the facilities made available by their furniture manufacturer.
Viability	[V1]	... does not use panel materials exceeding a (total) cost of €20.
Sustainability	[S1]	... implements the optimized panel.
	[S2]	... is modular to allow for flexibility in amount of condiment compartments, avoiding unnecessary material use
	[S3]	... uses its material efficiently, using as little material as possible.

Table 5. Requirements for the second project challenge visualized.







LOW  
MED  
HIGH

ACME

MADE IN  
ENGLAND



## CHAPTER 4

# Materials

*Market research is conducted to find sustainable alternatives to the four components currently used inside the panel. Per component the set requirements are used to assess the most promising available options. The best option is then used in several physical tests to confirm these theoretical optimizations.*

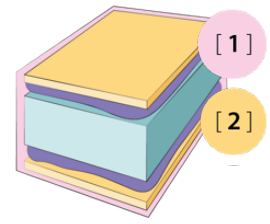
## 4.1 Laminate

### CB1 + coating

The most important component of the panel is the laminate [2]. The laminate is used to cover both planar sides of the panel providing both protection and aesthetic value. Regrettably, the currently used CB1 laminate discolors and distorts in user context, reducing its appeal. Thus, a coating [1] is needed to provide protection. Although a glass sheet could also suffice, this would limit the design freedom of the furniture designers. Market research on available sustainable coatings gave four most promising options based on their publicly available list of ingredients, certificates and price (table 6). The costs are based on calculations and substantiated estimations which can be found in Appendix A. The most promising options are the floor lacquer from BioPin and the clear lacquer from BioPin, Agliaia and Auro. The BioPin clear lacquer was assessed as the best option. Its VOC level ranked highest and most of its content is biobased. These two factors are considered positive to the coating's sustainable character. The absence of waste content is not considered unfavorable for the sustainable character of the coating as this is simply not yet available.

Due to an error, the BioPin floor lacquer was bought for physical assessment, instead of the clear lacquer.

Though its appearance is different, and it has a slightly higher VOC content, most of its other ingredients are the same. Therefore, it is assumed that its properties can represent those of the clear lacquer.



The lacquer is applied to small samples of the CB1 laminate with a paint roller (figure 25). Application of the coating has softened the rough pattern of the CB laminate, unfortunately reducing its tactility. This pattern is pressed onto the laminate during extrusion on purpose, to add a tactile experience. The color has also slightly changed giving the CB1 laminate a more yellowish appearance. Hopefully the advertised transparency of the actual proposed clear lacquer indicates it will not give this unwanted effect. During the application of the coating, small particles like dust started to stick to the surface, negatively influencing the surface's appearance. In the future, measurements need to be taken to prevent this from happening. Overall, sensorial appeal of the CB laminate is slightly reduced due to the application of the coating.

Coatings	BioPin - floor lacquer	BioPin – clear lacquer	Agliaia - transparent lacquer	Auro – transparent lacquer
	(BioHome (c), n.d.)	(BioHome(b), n.d.)	(Eco-verf, 2021)	(Auro(a), 2021)
Binding agent	Cooked mix of linseed oil, wood oil and modified colophony	Cooked mix of linseed oil, wood oil and modified colophony	Plant based oils and resins	
Solvent	Water	Water	No aromats	Water
Waste content	0%	0%	0%	0%
Biobased content	100%	100%	Most	Most
VOC level	1 g/L	< 1 g/L	400g/L	10 g/L
	● ● + ●	● ● ● ++	●● ● ● ●	● ● - ● ●
Price per panel	€11	€11	€19	€17
	● ● + ●	● ● ● + ●	● ● - ● ● ●	● ● - ● ● ●
Total	2	3	-3	-2

Table 6. Comparison of promising coatings for the optimized panel.

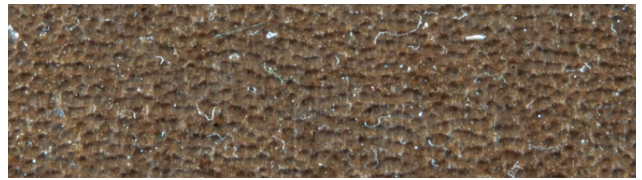
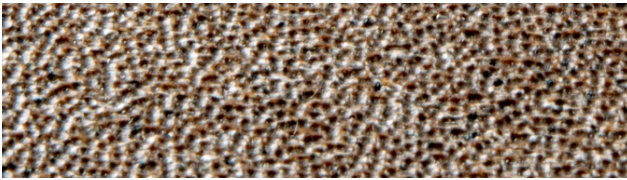


Figure 25. CB1 laminate pattern: without (left) and with coating (right).

The coated CB1 samples are divided over the three test set-ups: the dishwasher test, scratch test and UV test (figure 26). The dishwasher test resulted in loss of color and slight deformation (figure 27). The loss of color kept worsening in the days that followed. Nevertheless, compared to the original CB1 sample, the impact of the heat, water and cleaning chemicals was noticeably less. The coating has managed to protect the laminate from the scratch impact, as the CB1 material underneath remained unharmed (figure 28). However, the physical distortion in the coating is more visibly noticeable, probably due to the light color of the scratched lacquer in contrast to the laminate. The physical characteristics

of the scratch are similar to the behavior of thermoset materials when cut (Precious Plastic, 2020). This could explain that the scratch on the CB1 laminate (thermoplastic) is less noticeable. CoffeeBased employees have stated that discoloration and distortion by UV impact on the CB1 laminate happened before. Inconveniently, the UV test did not give similar results (figure 29). No discoloration nor distortion was visible after an hour inside the UV test. In its entirety, the coating has somewhat enhanced the resistance against impact from coffee corner impact. This would protect the CB laminate's aesthetic appeal.



Figure 26. Test equipment: UV test (left) and scratch test: without (middle) and with added weight (right).



Figure 27. CB1 laminate dishwasher test: before (left) and after without (middle) and with coating (right).

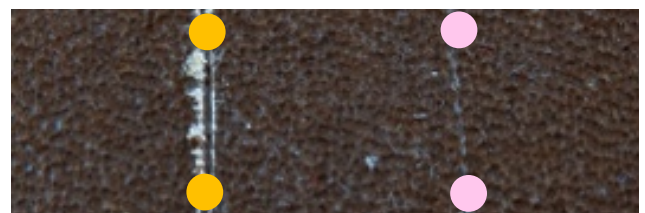
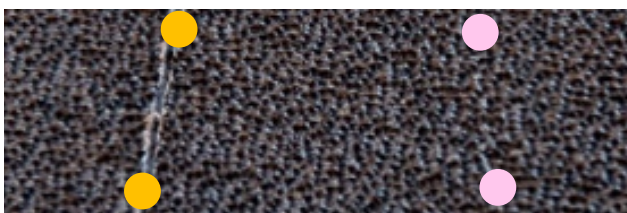


Figure 28. CB1 laminate scratch test: with (left) and without coating (right), with (yellow) and without added weight (pink).

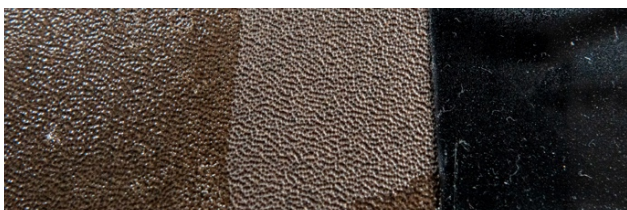


Figure 29. CB1 laminate UV test before and after: with (left) and without coating (middle) and covered (right).



### Preparation of CB2

The extruding facility has thus far not produced a laminate made from the CB2 material. In order to still perform tests on the material, hand-made samples with smooth surfaces needed to be made. A small production line was set-up using a table extruder and an old laundry mangler. Granulate of the CB2 material, used to manufacture coffee cups by injection molding, was molten and flattened using wooden sheets. The CB2 material that will eventually be extruded might contain different additives, as these differ per manufacturing type. Unfortunately, a flat surface was not achieved using the set-up (figure 30).

Therefore, the Applied Labs was consulted on the possibilities of using their machines (Applied Labs, 2021). A hot press and oven were available to produce samples. A square from 15x15 cm was milled from an aluminum sheet in which the granulate could be melt (figure 31). The bottom-side of the oven sample and both sides of the hot press sample were considered most suitable for

testing. The used set-up and evaluation of the produced samples can be found in Appendix B.

### CB2 + treatments/primer

To determine whether the CB2 material is suitable to replace the CB1 material as laminate, one feasibility test and two desirability tests need to be conducted. Because CB2 material is chemically equal to polyethylene (PE), it can be categorized as a polyolefin, and is likely to be just as troublesome to adhere.

To verify this, the polarity will be measured, which will indicate easiness to adhere (section 2.2). One way of doing this is by placing an oil and water droplet on the surface of the CB2 sample (figure 32). The smaller their contact angle, the more similar the polarity of the two substances. The results of this test indicate that the hot press sample is more polar, while the oven sample is more dispersive. As the samples are made from the same granulate, this is not possible, thus the test results are rendered invalid.

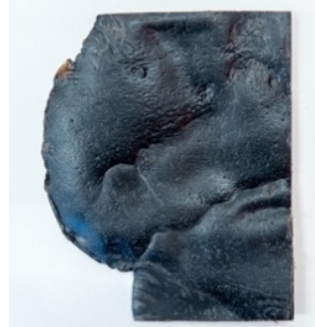


Figure 30. Set-up of table extruder and laundry mangler (left) and produced unviable CB2 laminate sample (right).

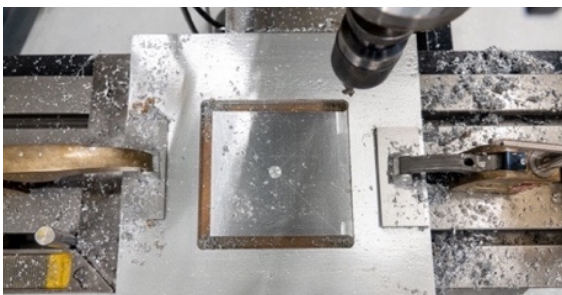


Figure 31. Set-up to mill the mold (left), produced CB2 sample by hot press (middle) and oven (right).

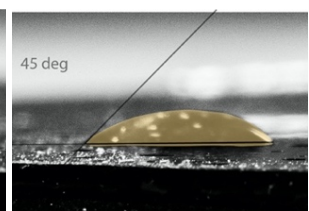
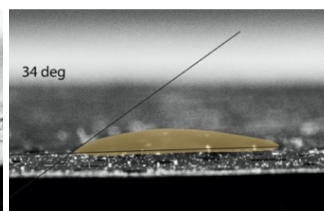
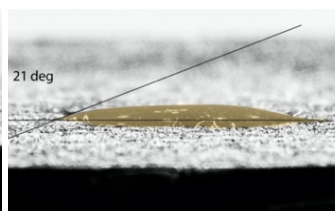
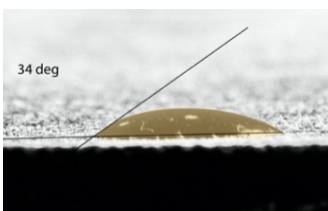


Figure 32. CB2 sample oil and water droplet test: hot press sample (left) and oven sample (right).

Two samples were sent to a surface treatment facility for professional testing, to measure the surface free energy by using a dyne solution (figure 33). If the solution stays intact for more than 2 seconds, the surface tension of the solution is equal to the surface free energy of the sample. For better visibility of this, a green/orange color dye is added to the solution (figure 34) (Nazdar, 2016). Fortunately, both CB2 samples have a higher surface free energy than predicted, meeting the requirement. The hot-press sample gave a result of 48 dyne/cm, whereas the oven sample's result was 40-42 dyne/cm. Surprisingly, these results are more similar to that of a PET sample (44.6 dyne/cm) (Arend's Corona treatments, 2021). A quick scan from a Plastic Scanner from a fellow student also indicates that the surface of CB2 resembles PET (Plastic Scanner, 2021). Perhaps explainable by the added SCG and additives.

It was unclear whether the CB2 material would be scratch- and UV resistant, which is why the following two tests were done. The scratches caused by the scratch test are smooth; no material is pushed aside (figure 35). The scratch test used on the hot-press sample without a brick is not even visible. The scratch impact seems similar to that of the CB1 laminate. The UV test was done on both CB2 samples, with a third of the sample coated, a third without additions and the last bit covered by tape

(figure 36). Unfortunately, because the UV test proved useless while testing de CB1 + coating, the results of this test on the CB2 samples are also deemed meaningless. Thus, the UV resistance of the CB2 material remains unclear.

A surface treatment can be used to temporarily add more polar groups to the surface, increasing its polarity. This is achieved by shooting atmospheric plasma through a nozzle onto the surface. The impact of the corona treatment is measured, by using a similar dyne solution as before. Because the enhancement is only temporary, it is not possible to do an adherence test. Thus, the conclusions need to be drawn from the provided measured data. The surface free energy of the hot-press sample was increased to 63 dyne/cm because of the treatment. The increase of 31.25% is similar to what happens with PE once its treated (Adhesives(b), n.d.). The tension in the oven sample also increased to 63 dyne/cm, with a 50-57% increase. Even after treatment, both samples would not have a surface free energy high enough to be compatible with a phenol-formaldehyde adhesive or coating. Also, the equipment for these treatments is expensive. To be a viable option, the panels would need to be produced in another facility, that already owns similar equipment.



Figure 33. Zoomed-in pictures for surface free energy measurement of CB2 sample by hot press (left) and oven (right).

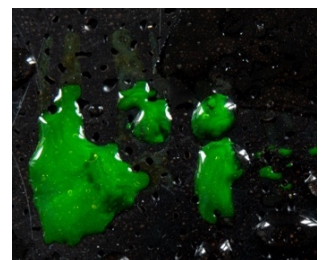


Figure 34. The hot press CB2 sample, including the dyne solution by Arends Corona Treatments.

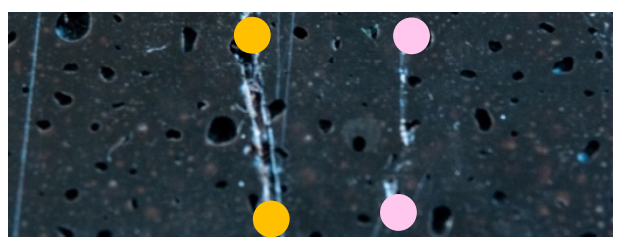
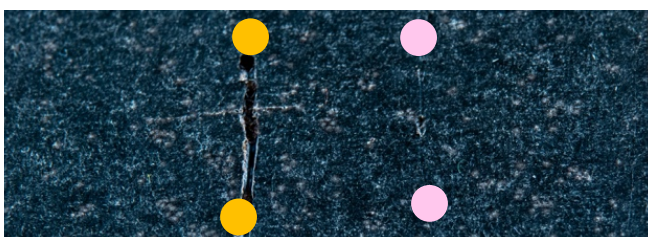


Figure 35. CB2 sample scratch test with and without brick: hot press sample (left) and oven sample (right), with (yellow) and without (pink) added weight





Figure 36. CB2 sample UV test before and after: hot press sample (left) and oven sample (right).

Compared to this chemical improvement, primers can provide a cheaper and more accessible alternative to enhance adherence of surfaces. Market research on available sustainable primers led to three possible options (table 7). Based on the remarkably low price and its 100% biobased content, the Kreidezeit primer was selected. Unfortunately, improvements in adherence made by the application of the primer cannot be measured in a similar fashion as the surface treatment. Therefore, adherence is tested the old-fashioned way, by attaching small pieces of MDF to the CB2 samples with and without using the primer. By comparison, it is determined which piece of MDF is easier to remove, implying that the joint is less fixed. Unfortunately, with this specific primer, the joints were easier to disassemble, suggesting a decrease in adherence (figure 37).

**Choice of laminate**

The choice of laminate should be based on whether an integral solution is provided, to improve the appearance as well as the sustainable character. The CB2 material is recommended as laminate. This, because it is predicted to function better in the desired user context, mostly due to its guaranteed protection against heat, water and cleaning chemicals. Whereas a coated CB1 laminate is only slightly more protected than before. This preference is not based on its scratch- and UV resistance, as the tests gave equal results respectively. Furthermore, choosing the CB2 material would render the need for a coating unnecessary, improving the overall sustainable character of the panel.

Primers	EcoTex Pro-aqua isowood (Eco-bouwmaterialen, 2019)	Kreidezeit vegagrondering primer (BioHome(d), n.d.)	Auro nr. 117 isolation primer (Auro(c), 2021)
Noticeable		Compostable	
Waste content	0%	0%	0%
Biobased content	Most	100%	Most
VOC level	0.01 g/L	0%	Unknown
	●●●● ++	●●●● ++	●●●● +
Price per panel	€20	€1	€18
	●●●● -	●●●● ++	●●●● -
<b>Total</b>	<b>1</b>	<b>4</b>	<b>0</b>

Table 7. Comparison of the most promising primers.

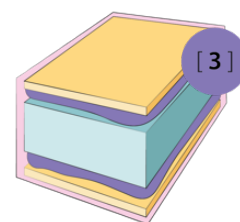


Figure 37. CB2 sample adherence test with and without primer: hot press sample (left) and oven sample (right).

## 4.2 Adhesives

The third component is an adhesive [3], which, as their name suggests, has the ability to adhere. By definition this indicates a relatively low surface tension and a sufficient cohesion within any adhesive. Therefore, this aspect of its technical feasibility is assumed present in all adhesives. The adhesive currently used is a PU hotmelt, thus the main sustainable improvement concerns the reduction in fossil-based content. In PU hotmelts, the solidification of molten plastic is what cures the bond. Without it, ingredients with VOCs are often added to initiate the curation. The desired reduced VOC level means no ingredients are added that could quicken the curation time. Though refurbishing could offer great sustainable impact, the capabilities of CoffeeBased do not allow for this. Therefore, adhesives that facilitate this delamination process are excluded from comparison (table 8). The costs are based on calculations and substantiated estimations which can be found in Appendix A. This leaves two viable options: BioImpact from Canect and Auro universal adhesive nr. 380. Unfortunately, the main ingredient in both cases is rubber, whose sustainable character is uncertain. It could originate from tree sap, a biobased source, but more common is a fossil-based origin (UCR, n.d.). Considering its low price, the BioImpact adhesive by Canect is considered the best suitable option.

The BioImpact adhesive is a surface contact adhesive, applied by using a spray tank. Unfortunately, this means it needs to be applied on the laminate and core by hand, requiring more manhours. After a few minutes, the materials can be pressed together, fixing the bond. The only ingredients containing VOCs that are inside the adhesive are emitted during production (Salesmen Canect, 2020). To reduce sample costs, a small aerosol spray is ordered to do a physical assessment, instead of an industrial sized tank.



Noticeable about the adhesive are the air bubbles that form when it's sprayed onto the CB1 laminate (figure 38). The applied pressure helps release the air inside these bubbles, this is mimicked by using the laundry mangler mentioned in section 4.1. The application by means of the aerosol spray is messy. It is assumed the bigger tank, commonly used in industrial manufacturing, will not give this problem. Distortion of the CB laminate could be prevented if the adhesive resists delamination. To test this, two CB1 samples are attached to a piece of plywood, one by normal wood glue and one by the BioImpact adhesive. Both are exposed to the dishwasher test (figure 39). The results show that the BioImpact adhesive remained fixed while the wood glued sample was delaminated. Therefore, the BioImpact adhesive is recommended.

Adhesives	CircuWall (Circuwall BV, n.d.)	DSM Niaga (DSM-Niaga, 2020)	Bio Impact Canect (Canect, n.d.)	Auro universal nr. 380 (Auro(b), 2021)
Noticeable	Product is returned and <b>adhesive</b> reused	Product is returned and layers reused	Made from citrus peels and natural rubber	Water, mineral fillers, natural rubber milk, colophony glycerol ester, linessed oil, milk casein, swelling clays, cellulose, potash, thiazole.
Waste content	0%	0%	Some	Unknown
Biobased content	0%	0%	Some	Most
VOC level	0%	0%	Little	0%
	● - ● ● ●	● - ● ● ●	● ● ● + ● ●	● ● ● + ● ●
Industrial application	● ● ● ● ++	● ● ● ● ++	● ● ● ● ++	● ● ● + ● ●
Costs / panel	Unknown	Unknown	€7,50	€30
	● ● - ● ● ●	● ● - ● ● ●	● ● ● ● ++	● ● ● ● ●
<b>Total</b>	<b>0</b>	<b>0</b>	<b>5</b>	<b>0</b>

Table 8. Comparison of the most promising adhesives.





*Figure 38. BiolImpact adhesive when sprayed onto the CB1 laminate.*

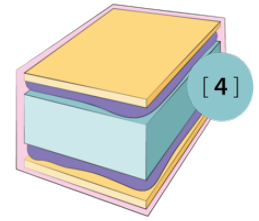


*Figure 39. Adhesion press set-up (left), plywood with CB1 laminate adhered by BiolImpact (middle, left side) and wood glue (middle, right side), results after dishwasher test (right).*

## 4.3 Core

The last component of the panel is its core [4], which provides mechanical strength to the panel. The most popular core materials have proven itself processible by standard furniture equipment. These materials include medium-density fiberboards (MDF), particleboards, oriented-strand board (OSB) and plywood (Precision Veneer, 2020). Currently, the panel produced by CoffeeBased contains a core that is considered standard for furniture panels, which is 18mm thick plywood (Gamma, 2020). The type of wood and the number of plies can have significant impact on the quality of the core in its entirety, which influences price and mechanical properties. As plies are made from virgin wood, its only sustainable improvement can be made by using no-added formaldehyde adhesives between the plies (E0 certification). This is only a small sustainable improvement. All, except for the plywood, are produced by applying heat and pressure to a mixture of wooden

particles inside a resin. Their sustainable character depends on the origin of the particles and the amount of resin that is used to keep it all together. For the content estimations of these core types, see Appendix A. Market research was conducted to find available sustainable core materials and the five with the most potential were selected (table 9). After an initial assessment of only the content properties of the core materials, a second assessment was done, taking the appearance of the sides into account. With an average thickness of 18mm, the sideview of the core takes up a big portion of the total panel, stating its importance in the panel's desirability. Finally, the Resysta NoWood core by FiberPlast scores the highest (figure 40 and 41).



Cores	Meditate Clear	ECOR <sup>4</sup> (4 layers)	Resysta NoWood	EcoBoard	Pure Glue Multiplex
	(Maiburg(a), 2021)	(ECOR, 2020)	(Resysta, 2021)	(Eco-boards, 2017)	(Maiburg(b), 2021)
Core type	MDF – not waterproof	Layered MDF	Extrusion-waterproof	Particleboard	Plywood
Waste content	0%	100%	60%	+ - 88.5% <sup>2</sup>	0%
Biobased content	89% <sup>1</sup>	100%	> 82%	+ - 88.5% <sup>2</sup>	91% <sup>3</sup>
VOC level	0%	0%	0%	0%	0%
	●●●+●	●●●●++	●●●●++	●●●+●	●●●+●
Mechanical properties	●●●●	●●●+●	●●●●	●●●●++	●●●●++
Usable right away	●●●+●	●●●●	●●●+●	●●●+●	●●●+●
Costs per panel**	€36	€48	€15	€30	€91
	●●●-●	●●●●	●●●●++	●●●-●	●●●-●
Design freedom	●●●-●	●●●+●	●●●●++	●●●-●	●●●+●
First assessment	-2	0	6	1	3
Aesthetic appeal	●●●+●	●●●-●	●●●●++	●●●-●	
Second assessment	-1	0	8	-1	

Table 9. Comparison of the most promising core materials.

<sup>1</sup> Based on average resin contents in MDF panels (Hong, 2017).

<sup>2</sup> Based on average resin contents in particleboards (Bhadewad, 2018).

<sup>3</sup> Based on average adhesive thickness (Purk, 2017)

<sup>4</sup> Excludes the material and production of adhering the 4 layers.



Figure 40. Side view of potential panel combinations, with Resysta NoWood (left), ECOR (middle) and EcoBoard (right).



Figure 41: The chosen core: Resysta NoWood by FiberPlast.

Resysta NoWood is an extruded panel made from husk, a side product from the production of rice (figure 46; Resysta, 2021). Although the Resysta NoWood is not made from wood, it can be processed as such, including the option to use CNC milling. In addition, it provides the option to weld pieces of the material together, removing the need for an adhesive in corner constructions. Sadly, this advantage exists because of its mineral oil content, which makes laser cutting undesirable. The laminate (+ coating) can protect the core from all user context

impact, but only on its planar surfaces. Therefore, the sides of the core are still likely to experience impact from heat, water and cleaning chemicals. To test whether a coating on the sides would be beneficial, the dishwasher test is conducted. Herein, a Resysta NoWood sample is partially coated by the chosen coating from 4.1 beneficial (figure 42). Results showed a discoloration in the area without the coating, reducing its appeal. Therefore, if the Resysta NoWood core is implemented, the sides of the panel should also be coated for protection.



Figure 42. Resysta NoWood dishwasher test: before (left) and after without (middle) and with coating (right).







## CHAPTER 5

# Panel

*Based on the assessment of sustainable component alternatives of the previous chapter, four panel concepts are presented. Each panel focusses on the optimization of different aspects, including user context resistance and sustainable performance. The list of requirements composed in chapter 3 is then used to evaluate the concepts, upon which a final panel concept is selected.*

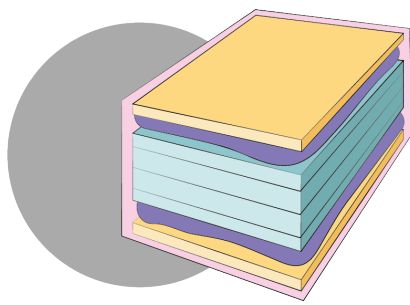


## 5.1 Concepts

All proposed component alternatives have benefits and downsides. Looking at the panel as a whole, trade-offs need to be made between the choice of components for an ideal combination. Although all suggested components can be ordered immediately, not all provide optimal properties. Nor do they all suit the current capabilities of CoffeeBased, as some of the proposed components require material and production development. Therefore, four different panel concepts are proposed, focusing on the optimization of four different aspects.

### Concept 1: “Geen hybride met formaldehyde”

The first concept only suggests a small change in the panel, that can be implemented directly. All current components are kept the same, except for the plywood core. Replacing the standard plywood core with a no-added formaldehyde version would immediately resolve the problem of VOC emittance (figure 43). This is mostly thanks to the hotmelt adhesive which does not require solvents or additive, therefore containing no additional VOCs. By remaining to use plywood, there is no improvement in the waste and biobased content (table 10).



#### Difference

**core**  
no-added formaldehyde  
adhesive in plywood

#### Impact

**[S3] reduced VOC content**  
different adhesives  
between plies

Figure 43. Panel concept 1 visual, and difference and impact compared to initial panel

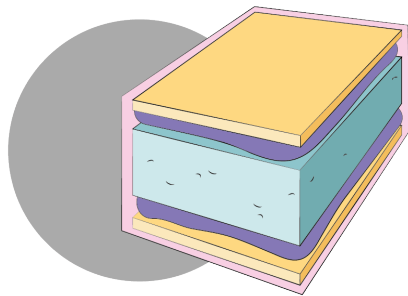
Component	Units	Thick-ness	Part proportion	Waste content in component	Biobased content in component	VOC level	Produced in the Netherlands
<b>Coating</b> [PU alkyd resin]	2x	0.5 mm	4.8%	0%	0%	0%	Yes
<b>Laminate</b> [CB1]	2x	0.8 mm	7.6%	20% >	Confidential	0%	Yes
<b>Adhesive</b> [PU hotmelt]	2x	0.2 mm	1.9%	0%	0%	0%	No
<b>Core plies</b> [Poplar]	1x	16.4 mm	78%	0%	100%	0%	Unknown
<b>Core adhesives</b> [no-added formaldehyde resin]	8x	0.2 mm	7.6%	0%	0%	0%	Unknown
<b>Concept 1 Improvement</b>	1x	21 mm	99.9%	1.5% <b>+ 0.0%</b>	83.6% <b>+ 0.0%</b>	0% <b>- 7.6%</b>	Medium <b>No change</b>

Table 10. Components of proposed panel concept 1.

**Concept 2: “Resysta, can’t resist ya”**

All components suggested in the second concept can also be bought right away, using a combination of the best assessed coating, adhesive and core proposed in chapter 4 (figure 44). The clear lacquer managed to provide some protection, and the adhesive managed to prevent delamination. The Resysta NoWood core

provides a cheap way for sustainable improvement, while still incorporating the core’s appeal. This combination increases the waste content, whilst roughly keeping its biobased content and VOC level unchanged (table 11).



**Difference**

**coating**  
BioPin transparant lacquer  
**adhesive**  
BioImpact from Canect  
**core**  
Resysta NoWood

**Impact**

**[S1] increased waste content**  
while still incorporating the core’s appeal

Figure 44. Panel concept 2 visual, and difference and impact compared to initial panel

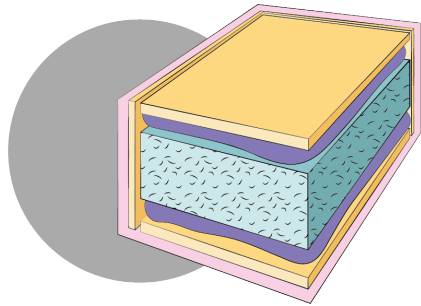
Component	Units	Thick-ness	Part proportion	Waste content in component	Biobased content in component	VOC level	Produced in the Netherlands
<b>Coating</b> [BioPin Varnish]	2x	0.5 mm	4.3%	0%	100%	< 1 g/L	Yes
<b>Laminate</b> [CB1]	2x	0.8 mm	7%	>20%	Confidential	0%	Yes
<b>Adhesive</b> [BioImpact Canect]	2x	0.2 mm	1.7%	0%	75%	Low	Not yet (UK)
<b>Core</b> [Resysta NoWood]	1x	20 mm	87%	60%	82%	0%	No
<b>Concept 2 Improvement</b>	1x	23 mm	100%	>53.6% <b>+ 52.1%</b>	82.1% <b>- 1.5%</b>	6% <b>- 1.6%</b>	Medium <b>No change</b>

Table 11. Components of proposed panel concept 2.

**Concept 3: “All aboard, the ecoBoard!”**

This concept implements the same coating and adhesive as Concept 2 but uses a different core material (figure 45). Despite its higher price, an EcoBoard core is chosen to achieve a higher sustainable value. Because this material is not aesthetically pleasing, the otherwise unattractive sides of the panel will be covered by attaching an edge band. Therefore, the development of

a CB1 laminate edge band is proposed. Since the amount of edge band material needed depends on the design of the furniture, this additional material is not incorporated into the calculations. Overall, this concept would increase the panel’s waste content as well as the biobased content, although unfortunately most VOC emitting materials remain (table 12).



**Difference**

additional edge band  
from CB1 material  
**coating**  
BioPin transparant lacquer  
**adhesive**  
BioImpact from Canect  
**core**  
EcoBoard

**Impact**

[S1] increased waste content  
while eliminating importance  
of core appearance  
[S2] increased BioBased  
content

Figure 45. Panel concept 3 visual, and difference and impact compared to initial panel

Component	Units	Thick-ness	Part proportion*	Waste content in component	Biobased content in component	VOC level	Produced in the Netherlands
<b>Coating</b> [BioPin clear lacquer]	2x	0.5 mm	4.8%	0%	100%	< 1 g/L	Yes
<b>Laminate</b> [CB1]	2x	0.8 mm	7.6%	>20%	Confidential	0%	Yes
<b>Adhesive</b> [BioImpact Canect]	2x	0.2 mm	1.9%	0%	75%	Low	Not yet (UK)
<b>Core</b> [EcoBoard]	1x	18 mm	86%	97%	97%	0%	Yes
<b>Concept 3</b>	1x	21 mm	100%	84.9%	95.2%	6.7%	Mostly
<b>Improvement</b>				<b>+ 83.4%</b>	<b>+11.6%</b>	<b>- 0.9%</b>	<b>Yes</b>

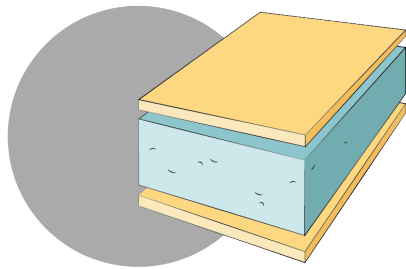
Table 12. Components of proposed panel concept 3.



**Concept 4: “Let’s rice to higher levels with coffee.”**

As stated in Chapter 4, it is predicted that a CB2 laminate will be okay at maintaining its aesthetic value in its desired user context, as heat-, water- and cleaning chemical resistance is guaranteed. Troubles with adhesion are predicted by the surface free energy measurements, which is why Resysta NoWood is suggested as core material (figure 46). This combination

can be welded together, rendering the need for an adhesive unnecessary. Moreover, the risk of delamination is reduced using this adherence technique. The amount of biobased content is similar to the initial panel, whilst its waste content is noticeably increased. All this, without the common unfortunate addition of VOCs (table 13).



**Difference**

**laminate**  
CB2 compound  
-  
**core**  
Resysta NoWood

**Impact**

**[S1] increased waste content**  
while still incorporating the core’s appeal  
**[S3] reduced VOC content**  
no adhesives or coatings

Figure 46. Panel concept 4 visual, and difference and impact compared to initial panel

Component	Units	Thick-ness	Part proportion*	Waste content in component	Biobased content in component	VOC level	Produced in the Netherlands
<b>Laminate [CB2]</b>	2x	0.8 mm	7.4%	15%	Confidential	0%	Yes
<b>Core [Resysta NoWood]</b>	1x	20 mm	92.6%	60%	82%	0%	No
<b>Concept 4</b>	1x	21.6 mm	100%	57%	82.9%	0%	Medium
<b>Improvement</b>				+ 55.5%	- 0.7%	- 7.6%	No change

Table 13. Components of proposed panel concept 4.

## 5.2 Assessment

The concepts are assessed using the list of requirements (table 14). As no concept was able to solve all problems, it is assumed that the 'perfect' panel does not (yet) exist. Therefore, prioritization is required. As the goal of this project is to provide a sustainable alternative to their original panel, it is recommended to implement concept 3.

Nr.	The panel ...	Concept 1	Concept 2	Concept 3	Concept 4
[D1]	... is applicable to multiple purposes, like furniture.	●●●+●	●●●+●	●●●+●	●●●+●
[D2]	... does not distort during production or use, thus maintaining the surface texture.	●●-●●	●●-●●	●●-●●	●●●●++
[D3]	... does not discolor during production or use, thus maintaining its coffee color.	●●-●●	●●-●●	●●-●●	●●●+●
[D4]	... does lose its coffee smell.	●●-●● Covered by coating	●●-●● Covered by coating	●●-●● Covered by coating	●●●+●
[F1]	... is suitable for traditional furniture panel manufacturing machines specifically CNC milling.	●●●+●	●●●+●	●●●+●	●●●+●
[F2]	... abides mechanical alterations, like screws.	●●●+●	●●●+●	●●●+●	●●●+●
[F3]	... is producible in standard size of 1.22 by 2.44 m.	●●●+●	●●●+●	●●●+●	●●●+●
[F4]	... has a maximum tensile strength of 8.5 MPa.	●●●+●	●●●+● No, but salesmen says it'll suffice	●●●+●	●●●+● No, but salesmen says it'll suffice
[F5]	... has a minimum stiffness of 1800 MPa.	●●●+●	●●●+● No, 800 MPa, but salesmen says it'll suffice	●●●+●	●●●+● No, 800 MPa, but salesmen says it'll suffice
[F6]	... is usable right away to be efficient.	●●●●++	●●●+● Different adhesion technique	●●-●● Edge band not yet produced	●●-●● CB2 laminate not yet produced
[F7]	... does not require extra manufacturing facilities.	●●●●++	●●●+●	●●-●● No: Edge band production Yes: Edge band attachment equipment	●●-●● Sheet welding equipment
[F8]	... has compatible components, thus the CB laminate should have a surface free energy of:	●●●+● Assumed yes.	●●●+● Assumed yes.	●●●+● Assumed yes.	●●-●● Different melt temperatures for Resysta as CB2
	minimally 38 dyne/cm (in general)	●●●+● Assumed yes.	●●●+● Assumed yes.	●●●+● Assumed yes.	●●●+● CB2: yes.

	minimally 73 dyne/cm (in case of a water-based adhesive/coating)				No adhesive
	minimally 68.4 to 79.9 dyne/cm (in case of a phenol-formaldehyde adhesive/coating)				No adhesive
	minimally 20 dyne/cm (in case of PU hotmelt adhesive)				No adhesive
[V1]	... has reduced market risk, by only implementing components that can be bought off-the-shelf, ensuring market acceptance.				Production needed; assumed to resemble Existing laminates
[V2]	... does not implement components that make the panel cost more than €50 in total.				No costs for adhesive or coating or extras
		Core is €91	€55 for all materials	€70 for all materials	€35 for all materials
[S1]	... has a higher waste content than 1.5% in the total panel.	Still 1.5%	53.6% >	84.9%	57%
[S2]	... has a higher biobased content than 83.6%.	Still 83.6%	82.1%	95.2%	82.9%
[S3]	... has lower chance of VOC emitting content than 7.6%; including production and use.	0%	6% some	6.7% some	0%
[S4]	... originates and allows producibility and assembly within Dutch borders.	if FSC wood is local is unknown	Rice husk is not locally peeled - BioImpact not in NL yet	BioImpact not in NL yet	Rice husk is not locally peeled - Sugarcane is not local
<b>Total</b>		<b>7</b>	<b>8</b>	<b>9</b>	<b>11</b>

Table 14. List of requirements used to assess the four panel concepts.



## 5.3 Proposal

The panel by CoffeeBased was aimed to have better sustainable performance and user context resistance. This panel consists of a biobased content of 95.2%, waste content of 84.9% whilst only containing 6.7% content that could emit VOCs. Aside from the adhesive, all components originate from within the Dutch borders. The visual comparison of the original panel compared to the proposed optimized panel is shown in figure 47. As for the user context resistance, because the BioPin coating only provides a slight protection, it is recommended to apply multiple layers.

This proposed panel concept has a production process of seven steps. First, the EcoBoard core and the CB1 laminate will be sprayed using the BioImpact spray tank from Canect. Then, a pause of approximately 5 minutes is necessary for the low level of VOCs in the solvents to evaporate. Hereafter, they can be pressed together using the press that the panel maker currently already uses. For the next step, the edge banding machine of the

furniture maker will be used. The machine automatically unwinds edge band material from a coil (figure 48). Per panel side, the machine attaches the edge band, cuts the 2mm spare material off and directly sands the edges. When all sides are covered, the coating can be applied using a roller.

CoffeeBased has not produced an edge band from CB materials thus far. To produce this, the same extrusion process as for the laminate can be used to produce a 1 or 2 mm thick sheet. Extra knives will need to be added at the end of the production line, cutting the sheet into strokes that can be wound around empty coils. There are two types of edge bands that can be fed into the edge banding machine. The first is pre-glued. The edge banding machine merely heats up the glue with hot air, before pressing it onto the sides. The second gets glued by the machine. For more information on the edge band production, see Appendix C.



Figure 47. Original panel manufactured by CoffeeBased (left) and proposed optimized panel (right).



Figure 48. Scrap material of the CB1 laminate, draped around an old filament coil (left) and used to cover the proposed optimized panel (right).

The price of the total panel was aimed at €50 each. Unfortunately, due to the choice of core this has increased to €70 each (table 15). Just like all trade-offs, price can also be taken into account in panel selection. If the furniture designer or end user does not want to pay this price, the components should be reconsidered.

Apart of the biobased content, the sustainable value of the panel is its use of waste materials. The SCG inside the CB1 laminate provides visual and olfactory conformation of the harnessed waste material and does so by providing the panel with aesthetic appeal. The high volume of waste implemented in the core will not be visible because it will be covered on all sides. This makes

clear advertisement of its sustainable character to the user all the more important. An example of how this can be done is by visual representation of the amount of SCG that is reused inside the CB1 laminate. For clarity reasons, this should be translated into the cups of coffee that were consumed to produce this amount of SCG waste. The results of such a calculation show that per square meter of CB1 laminate, SCG from 30 cups of coffee is saved (figure 49). For CB2 laminate this would only be 16 cups, explainable by its lower waste content and its lower density. The EcoBoard takes up a volume of 54 liter per panel. This is translatable into 38 kilos of saved agricultural waste per panel (figure 50). See Appendix D for the calculation.

Nr.	Component	Price / quantity	Quantity / panel	Price / Panel
[1]	Coating [BioPin clear lacquer]	€16,96 / 0.75L <sup>1</sup>	75-85 mL / m <sup>2</sup> <sup>1</sup> 450-510 mL of coating / panel	€12
[2]	Laminate [CB1]	+ - €10 / laminate	2 laminates / panel	€20
[3]	Adhesive [BioImpact Canect]	€300 / tank	240 m <sup>2</sup> / tank 6m <sup>2</sup> / panel	€7,50
[4]	Core [EcoBoard]	-	-	€30
<b>Concept 3</b>				<b>€70</b>

Table 15. Price calculation.  
<sup>a</sup> (BioHome(a), n.d.)

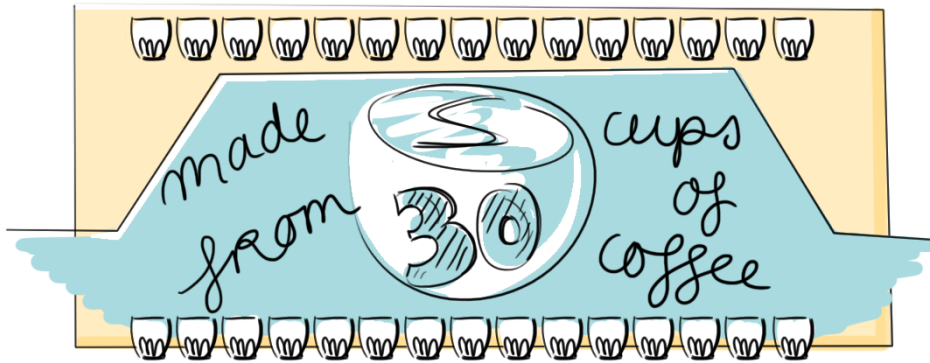


Figure 49. Example of advertising the 30 cups of coffee that were needed to produce this panel.

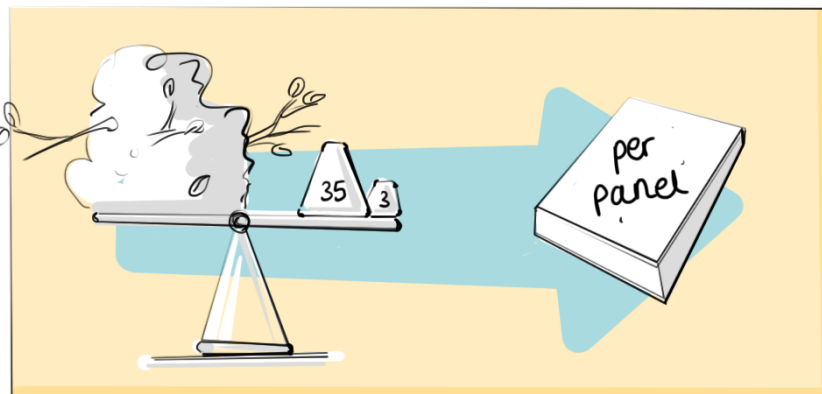
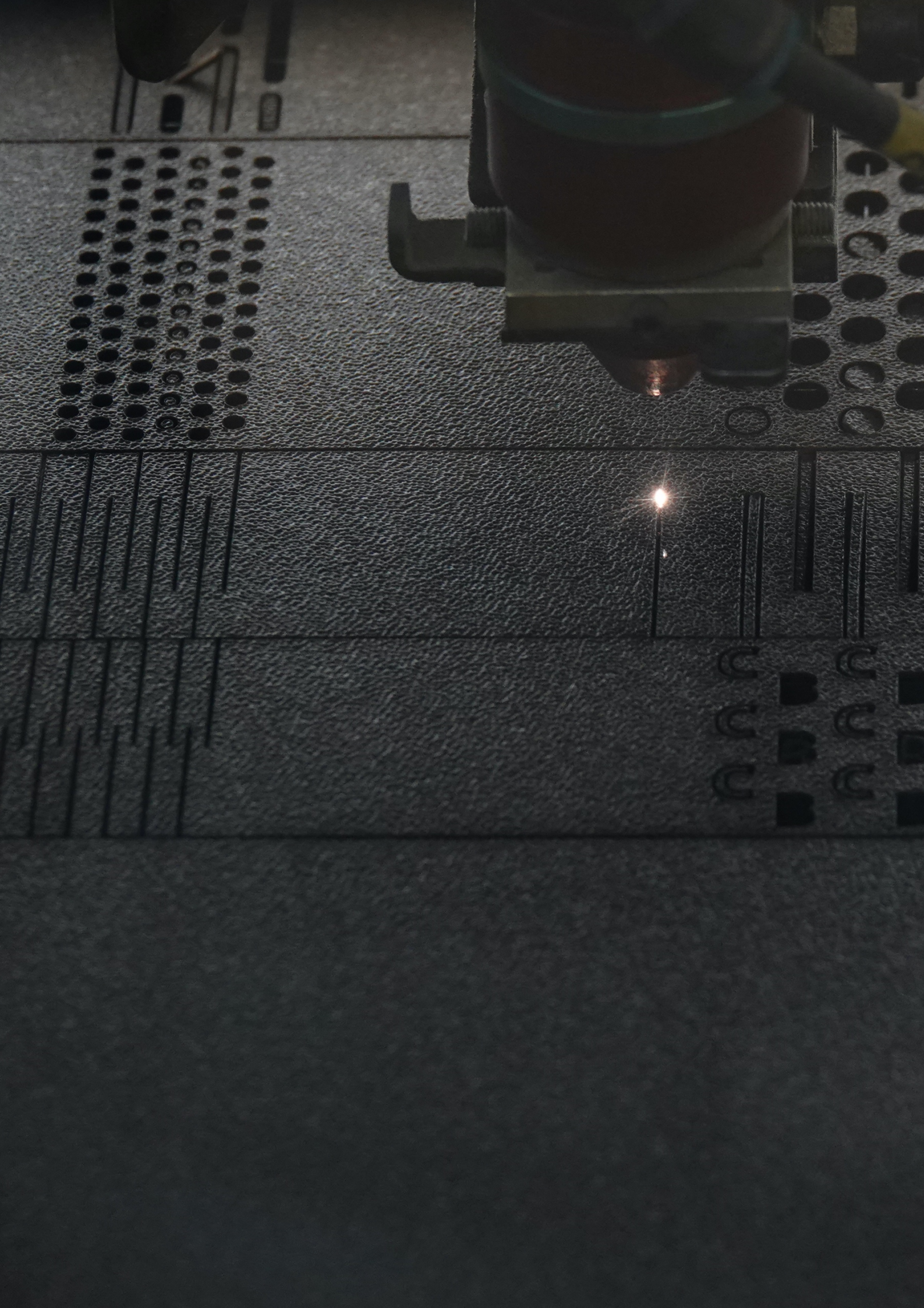


Figure 50. Example advertisement for the 38 kilos of agricultural waste that were needed to produce this panel.







## CHAPTER 6

# Condiment Organizer

*In this chapter the design process is summarized that led towards the proposed condiment organizer design. Design questions helped guide the ideation process that led to clusters of ideas. The four most promising ideas were presented to the client. The selected idea was conceptualized, during which a few manufacturing challenges emerged. These were tackled and a final design and prototype was created.*

## 6.1 Ideation

At the start of the ideation process, the set requirements were examined, and design tools were explored. During the extent of this process, the low aimed production price was vital in decision making. The how-to method was selected to help translate the requirements into design questions. Some of these could be answered via idea generation directly, others first required material testing or a brainstorm session. A meeting with CoffeeBased employees helped prioritize, which were the most important design questions to focus on:

*'How to communicate the sustainable character of the material?'*

*'How to make the appearance fit the form language of the existing CB coffee machine front and CB coffee station?'*

*'How to implement the existing CB products, like the plant pot and coffee cups?'*

*'How best to orient and display the condiments?'*

### Sustainable character

Methods to display the sustainable characteristics of the material were explored by conducting some tests on the CB1 laminate. Several techniques were explored, and a few were tested by laser cutting, sand blasting, stamping

and painting with white paint (figure 51). To execute laser cut advertising, the product should either be flat, or the laminate needs to be cut prior to implementation in the product. The other two methods are not applied by industrial machines, and as such they can be executed at all times, though all three methods are best to apply prior to coating. For all test results and generated sketches see Appendix E and F.

### Matching style

To illustrate the style of the CoffeeBased coffee machine front and coffee station, simplified clear shapes, color combinations and patterns were visualized (figure 52). The coffee station is made from the flat panels and its corners are sharp. During the span of this thesis, the design of the coffee station kept changing. For this reason, no additions specific to the current coffee station are taken into account, like the cup dispensers and fastening materials. The coffee machine that holds the vacuum formed CoffeeBased fronts, is more natural and not as rigid as the station. The color of both products is similar, though combining their distinct form languages can be a challenge.



Figure 51. CB1 communication test results by laser cutting (left), stamping (middle) and painting (right).

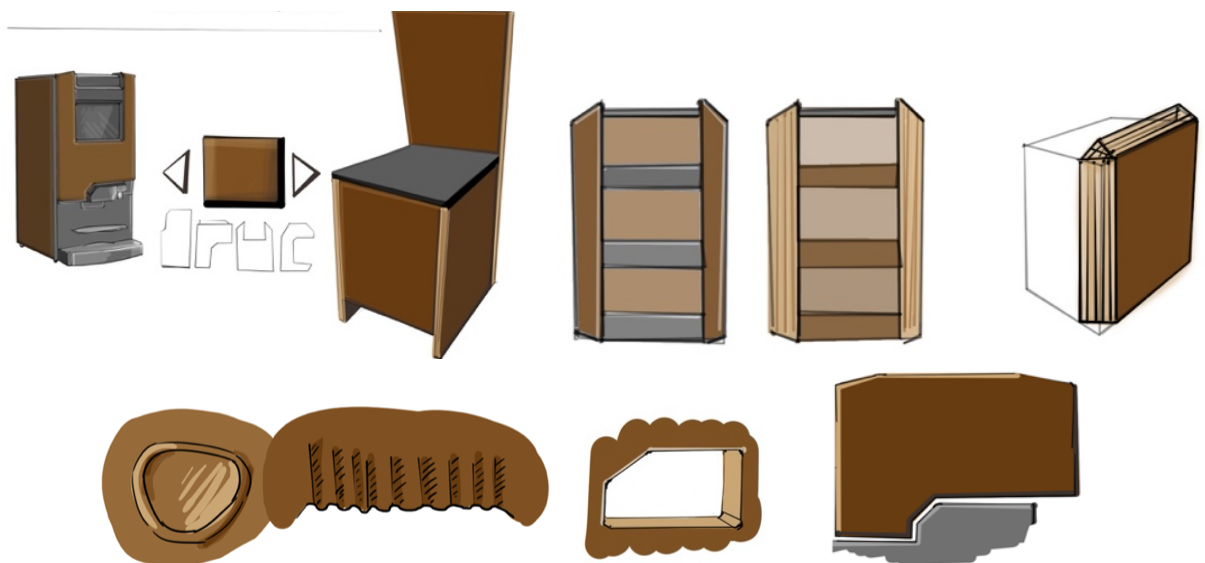


Figure 52. Sketches about the form language of CoffeeBased's coffee corner products

### Implementing current products

It is suggested to implement existing CoffeeBased products for several reasons. The first and most important reason is to reduce start-up costs. The purchase price of expensive molds can be prevented if the ones available are used. Secondly, developing new products with the CB material can be challenging, so using existing CB products provides ease. Also, it is

considered a sustainable advantage if the production of new molds is prevented, as well as its coinciding inevitable waste of failed products during the trial-and-error phase. A few sketches were made to find ways to implement existing CoffeeBased products, such as coffee cups and plant pots (figure 53).



Figure 53. Few ideas surrounding implementation of existing CoffeeBased products in the condiment organizer design.



## Orienting the condiments

The decision to produce a condiment organizer is simply to complete the existing coffee corner set. The purpose of a condiment organizer is to hold condiments in a user-friendly way, focusing on display, accessibility and easy refilling. To get more insight on user preference, a small brainstorm session was held (figure 54). As for user observation, the importance of presenting the type of tea flavor was raised. Next, the optimal orientation to grab the condiments was decided for the most popular ones: the stirring stick, milk cups, sugar sachets and tea bags. Most noticeable was the exclamation by one peer on her concern for spreading germs while grabbing a stick to stir. Often, these are oriented in a way that makes it inevitable to also touch the adjacent sticks. Seeing as how a coffee station is a communal area, this

is considered relevant. Unfortunately, the subject of refilling the condiments did not really inspire for ideas. These insights were used to generate ideas and set up a user scenario (see Appendix G and H).

## Idea generation

A few ideas were clustered and presented to CoffeeBased employees, in order to become more familiar with their style. Two axes were used to display the ideas in an orderly fashion (figure 55). On the horizontal axis the sketches were sorted by their form language (rectangular to circular) and on the vertical axis by their uniformness (separate compartments to a uniform shape). The sketches that suited the expectations of CoffeeBased best, are highlighted in yellow



Figure 54. User statements on the most popular condiments: tea bags, milk cups, stirring sticks and sugar sachets.

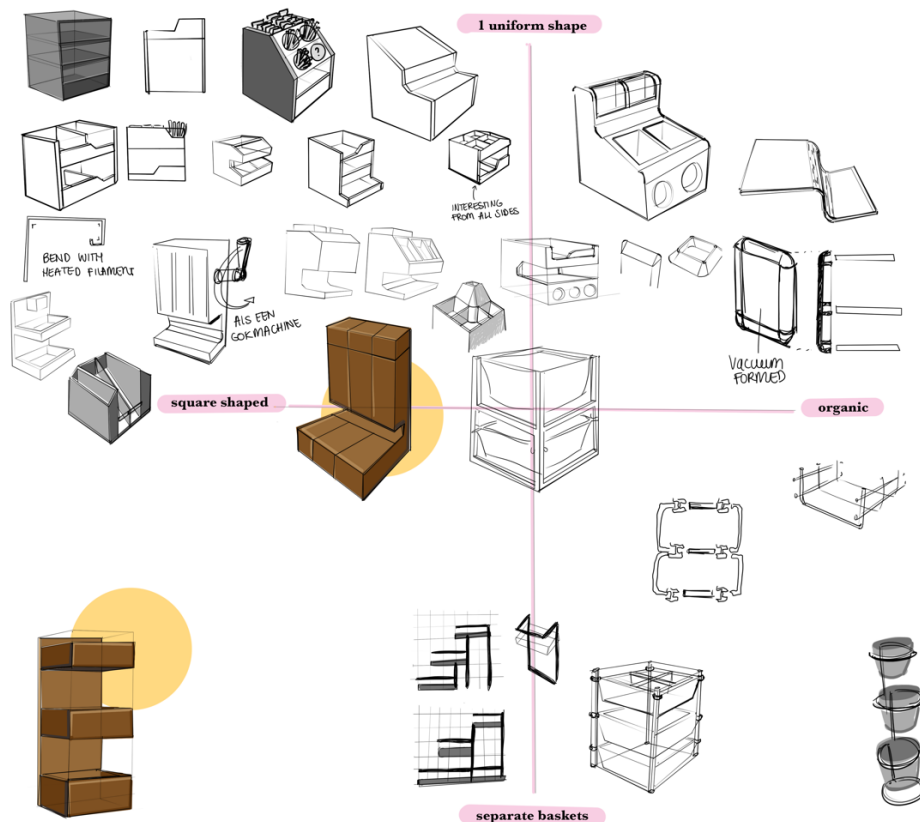


Figure 55. First generated ideas structured on axes.

### Most promising four ideas

At the end of the ideation process, the generated ideas were converged to four ideas. It is important to note that during this phase the material optimization, as shown in chapter 4, was still ongoing. Therefore, the first two ideas surround the notion that the Resysta NoWood core can be thermoformed. The first idea consists of two outer walls and adjustable baskets (mistakenly referred to as drawers in the picture) (figure 56). The shape of the baskets makes it easier to grab the condiments and the slit in the back makes the baskets easy to clean. The second idea implements the plant pots as baskets in a conic shaped frame that can be turned (figure 57). It provides the option to be placed in meeting rooms, where the condiments should be available from all sides.

The third idea is based on autonomy, providing the user with the tools to set-up the condiment organizer to their own preference (figure 58). Unfortunately, solving the mechanics behind this shape would be a challenge because of unequal weight distribution. The last idea implements the brainstorm insights by using a modular system, allowing for each condiment to be oriented in a specific way (figure 59). More elaborate explanation of these ideas can be found in Appendix I. The ideas were presented to CoffeeBased and it was decided to continue with the fourth idea. Its foremost benefit being the strong foundation upon which decisions were made, namely its condiment specificness.

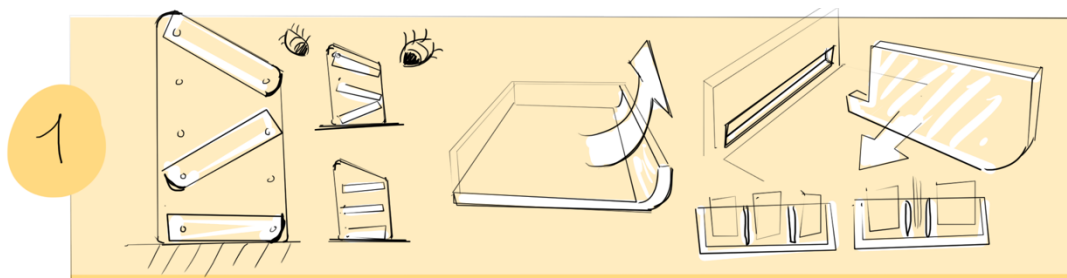


Figure 56. First idea: It's a basket case.



Figure 57. Second idea: Another round, please!

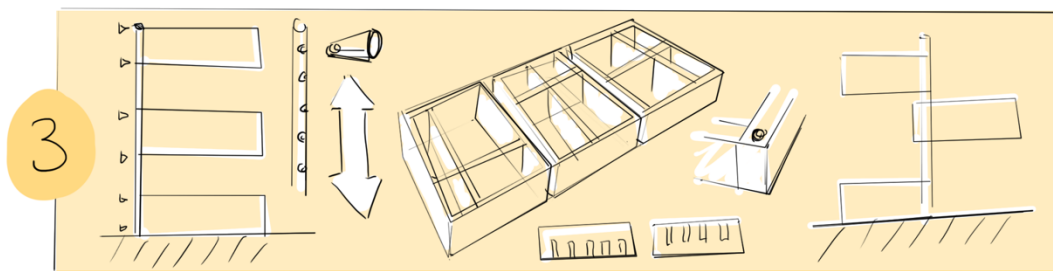


Figure 58. Third idea: Customized to taste.

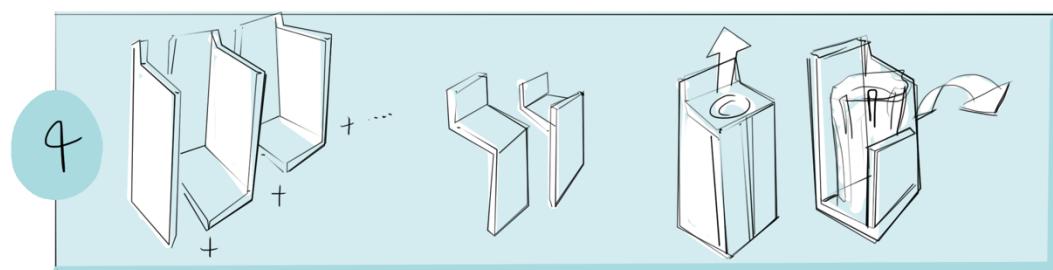


Figure 59. Fourth idea: Fits like a glove (compartment).

## 6.2 Conceptualization

The next step in the design process is the conceptualization, which takes the chosen idea 'fits like a glove (compartment)' and turns it into an actual concept. To turn this idea into a viable concept, several challenges were composed based on the requirements and client input. The challenges posed by the main requirements concerned the choice for material and product appearance. This, by requesting a manufacturable design implementing the optimized panel (see chapter 4) as well as the use of corresponding form language to the existing coffee corner products. The challenges derived from client input that most affected the design concerned customization. Allowing for multipurpose compartments as well as the option to house coffee cups and garbage. Several design tools, like quick prototyping, Illustrator CC, Photoshop CC and SolidWorks, were used to tackle these design challenges. All conceptualization sketches can be found in Appendix J.

### Expressed wishes

The original idea allowed the user to select as many compartments as desired, that could endlessly be attached. To still ensure proper fixation of the back

frame, the client has suggested to offer it pre-assembled. As a consequence, the production would differ per chosen design, which would call for endless production changes. To avoid these infinite custom designs, a selection of three different sized condiment organizers will be offered. All compartments are thereby required to be multipurpose (figure 60). With a pre-assembled back frame, users can still choose condiment specific fronts to their own preference. This allows for an affordable and easy option to switch fronts whenever a user is in want of change.

The client requested that besides the popular condiments, the CoffeeBased coffee cups also receive a designated spot in the condiment organizer (figure 61). Space is required for the hand to wrap around the cup, making the most viable spots for the coffee cups the left or right side of the condiment organizer. Conveniently, there are two different coffee cup sizes that might both need housing. It is considered best to make the cup compartment optional. This, because one of the coffee stations already provides an integrated cup dispenser, which is considered more hygienic.

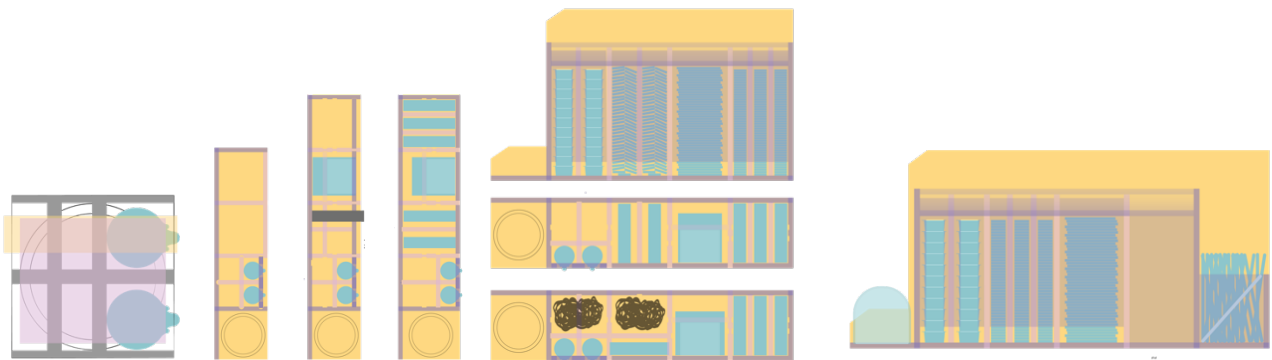


Figure 60. Exploration on how to fit all condiments inside the same compartment in Illustrator CC.

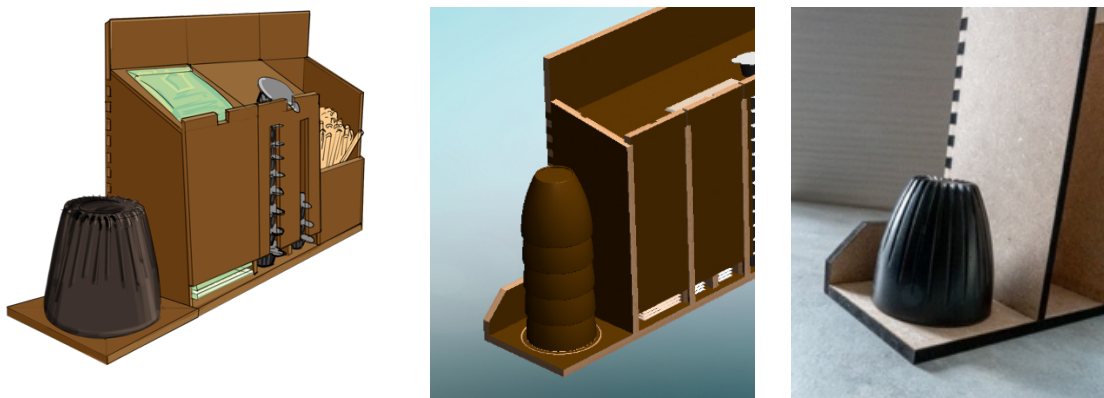


Figure 61. Designated coffee cup spot sketched and rendered in a render.



The user interaction in coffee corner context was discussed during the brainstorm session. It was pointed out that the wrappings of all condiments accumulate a lot of waste materials for which often no designated space is designed. However, all devised hygienic solutions to implement a garbage compartment reduced the aesthetic appeal of the design and made cleaning more difficult (figure 62). For instance, small plastic bags could contain milk cups and its remaining milk but would likely be visible from the outside. Additionally, steps like opening, emptying, replacing and closing a lid, would increase cleaning time and effort. A modular waste compartment would be easier to empty, but the issue with hygiene remains. All small slits and corners are difficult to clean, promoting the growth of bacteria. Therefore, it was decided not to implement a waste compartment in the design, assuming the coffee corner houses a garbage can nearby. Another point addressed the small openings and corners, making it difficult to get

rid of collected dust. As a solution, the housing keeps most dust out and if not, a slit is designed in the bottom at the back (figure 63). All parts are made from coated panels, thus making it possible to clean the condiment organizer using hot water with cleaning chemicals, as tested in Chapter 4.

**Manufacturability**

These decisions helped define the concept enough, to explore manufacturability. The first part is assembly. Unfortunately, the current production equipment does not allow for the adherence of such a small furniture design. The addition of the required extra mold would cause an increase in production costs, which is undesirable. Because the panels do not allow for the option to be glued together, it was decided to use a strong box joint connection (figure 64). Conveniently, this also minimizes the need for adhesives, reducing costs.

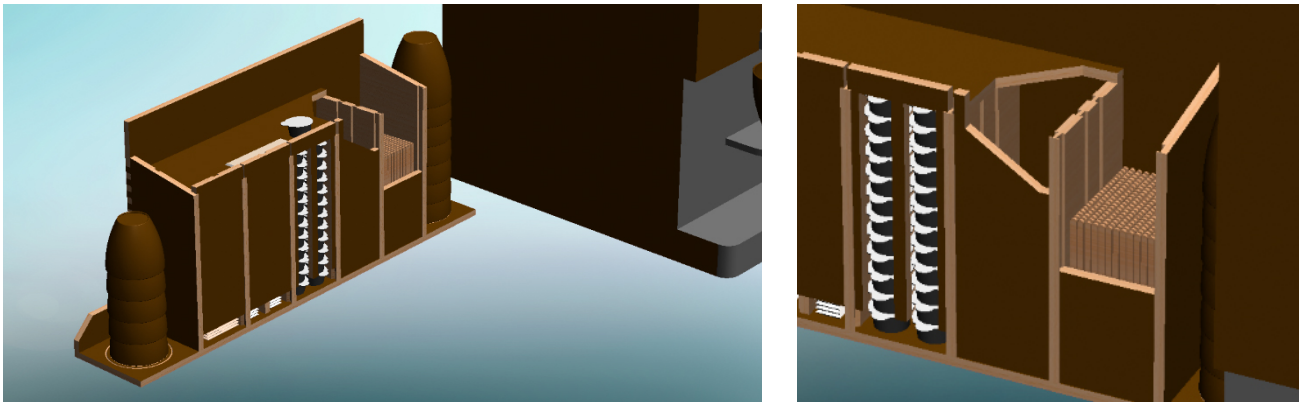


Figure 62. SolidWorks model including waste compartment next to a scaled model of the coffee machine.

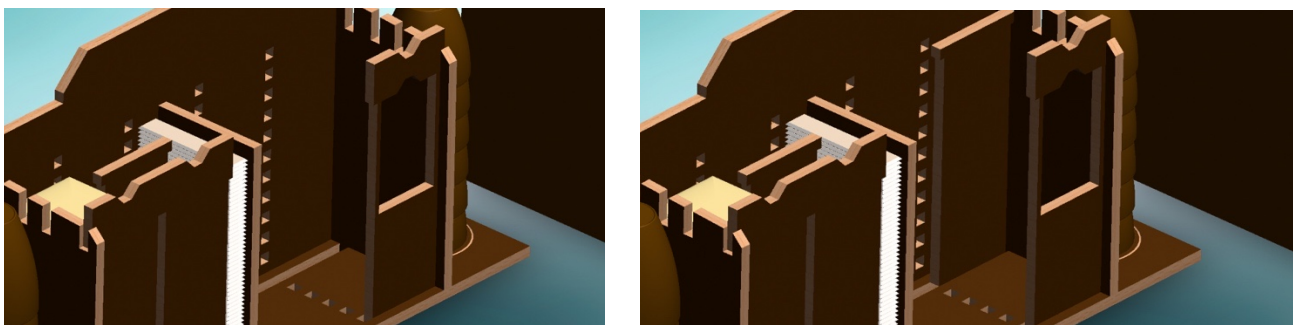


Figure 63. Slit in the back of the condiment organizer.

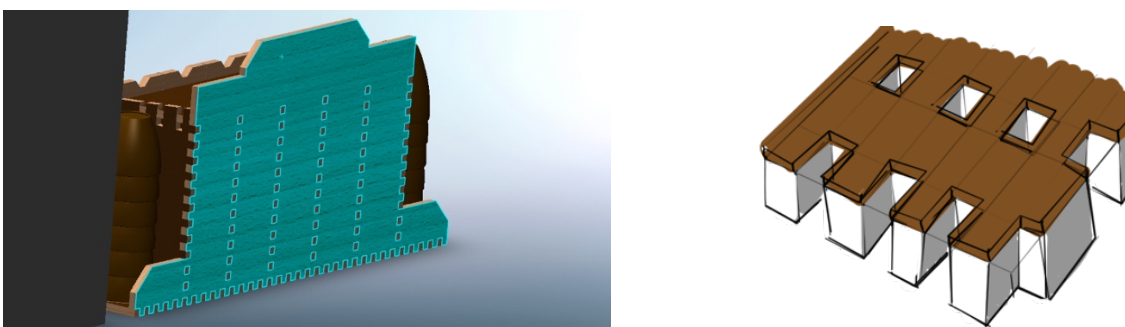


Figure 64. Box joint connection.

A box joint connection uses a combination of notches and gaps, notch with perpendicular corners. As a CNC milling cutter leaves rounded corners, an alternative cutting method is needed. Laser cutting does not only provide a perfect solution to this particular problem, but it is also cheaper, easier to set up and more material efficient (Woodlaser BV, 2021). Although it was originally required to use the existing production facilities, a previously established connection between CoffeeBased and a laser cutting facility deems this a viable alternative.

However, laser cutting the panel means the core cannot contain fossil-based resins nor have an open structure. The more resin and air are heated by the laser, the more the material tends to burn. Although the requirements state specifically to use the optimized panel as proposed in Chapter 5, it was decided not to implement this exact panel to avoid the risk of flame ignition by laser cutting of the EcoBoard core. The preferred alternative Resysta NoWood core poses the same problem (figure 65). Therefore, the implementation of an 8mm version of the no-added formaldehyde plywood core from panel concept 1 is chosen for this condiment organizer design. Although this panel has a lower waste content than the EcoBoard, it maintains a high biobased content whilst ensuring a low VOC level.

The thus far created concept uses CNC cut grooves to attach the alterable pieces. Since the chosen box joint

connection is used for all the fixed junctions, this would suggest using two different manufacturers. This inconvenience was also noticed while prototyping, as two different machines were suddenly necessary (figure 66). It would be both expensive and time consuming to have one manufacturer cut all laser cut pieces to size, and another adding grooves. Therefore, the method of joining the alterable parts will need to be rethought.

Next to a different core material, the proposed edge band is also not implemented in the condiment organizer design as the design's edges are not consistent. Also, delamination of the edge band might be risked when the box joint is assembled. As less mechanical strength and stiffness is required of the panels in the condiment organizer, a total thickness of 10 mm will suffice, see Appendix D for the calculation.

After the material choice, the second requirement stated a correspondence in form language and style with the existing coffee machine fronts and coffee station. Applying the same CB1 laminate and BioPin coating as the proposed optimized version of the coffee stations ensures overlap in visual appearance. As for the coffee machine front, its appearance is mimicked by implementing more variety in outer shapes, and the addition of naturally curved engravements (figure 67).

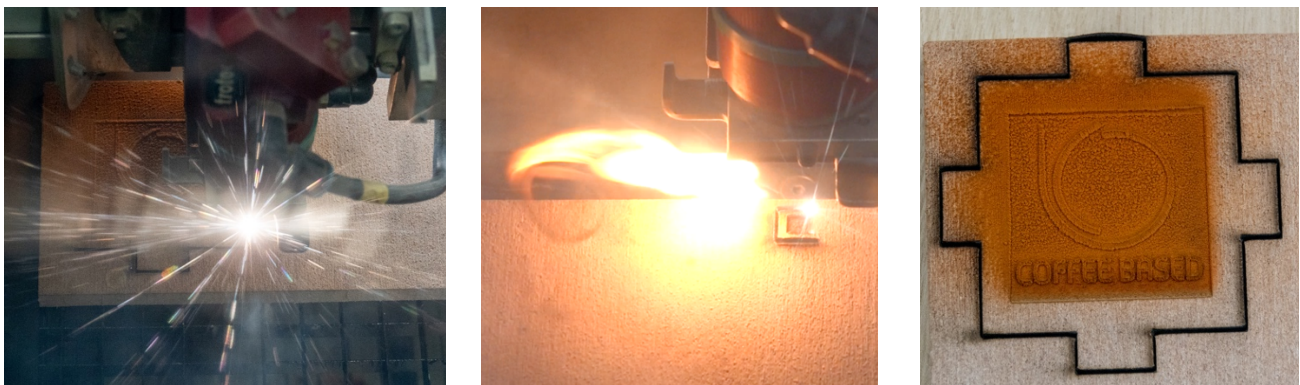


Figure 65. Laser cut test with the Resysta NoWood core without (left) and with flame (middle) and result (right).



Figure 66. Prototype left unfinished, as manufacturing with different machines turned out to be too time consuming.



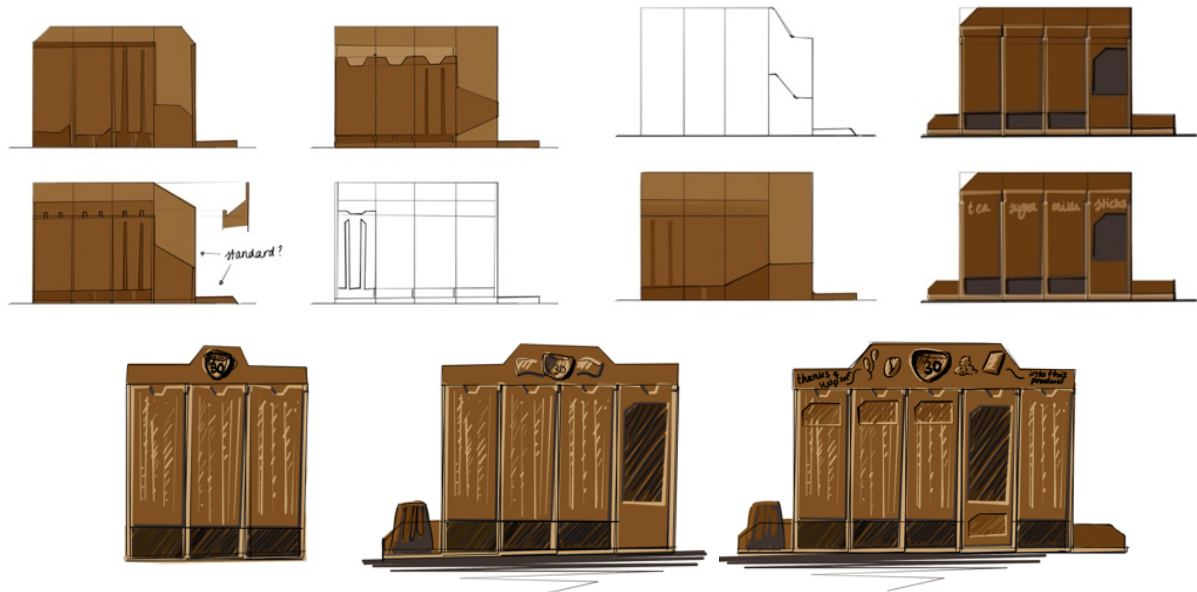


Figure 67. Three different sized condiment organizer designs.

There are different types of communication with the user within this condiment organizer design. Including possible advertising of the sustainable character of the product and guidance in what condiments are offered. The latter is mostly relevant due to the condiment organizer's closed-off design, and as the panels are not transparent the condiments are difficult to see right away. To ensure that the communication runs smoothly, it is crucial that the selected message and background colors have enough contrast, making the product more accessible to people with poor eyesight (W3C, 2010). The previously suggested communication methods, including laser cutting, stamping and painting, are applied on samples that could be tested with a contrast checker (Image-color, n.d.). Laser engraved letters or a plywood background only gives enough contrast with a font, when the font is 19pt or bigger. The most promising communication method is the white paint, as with a 12pt font size it is already acceptable to display text and logo's (figure 68). For all tests see Appendix K.

At last, all challenges are implemented in the concept design, which is given the name: 'Kovivol' (figure 69). This name was chosen because of its reference to the product being "full of Coffee", which in Dutch is translated to "koffie-vol". The material panel for this concept design can be laser cut, using an illustrator file that contains all parts efficiently arranged within an area of 1.22 times 0.6 meters. A prototype was made at the PMB using a requested laminated traditional plywood core (figure 70). The engravements almost doubled the production time to 1 hour of laser cutting. Inconveniently, the panel was only laminated on one side which is why a sheet press was used to laminate the other side as well (figure 71). The total price for the materials of €25 is needed for a 0.73m<sup>2</sup> design that contains 2 coffee cup spots, 2 tea (1 big and 1 small), 1 milk, 1 sugar and 1 stirring stick compartment, including 3 wall dividers (table 16).

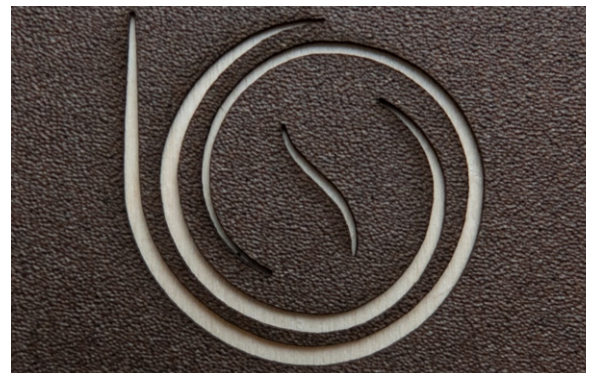


Figure 68. Condiment type highlighted in white on the prototype (left) and a laser cut sign (right).



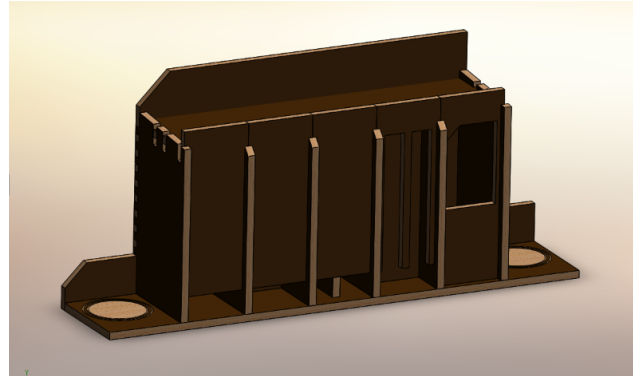
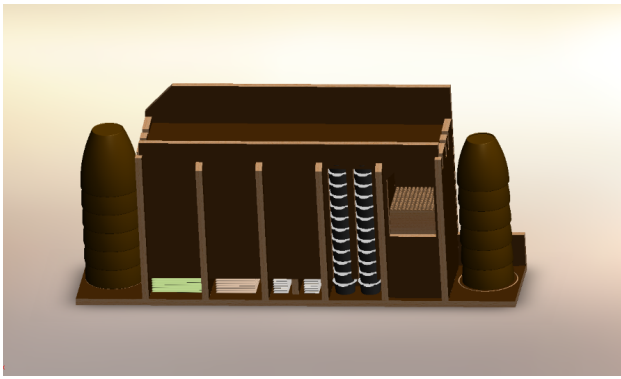


Figure 69. Computer render of concept design "Kovivol", front (left) and back (right).



Figure 70. Physical prototype of concept design "Kovivol".



Figure 71. Laminating other side of the panel by sheet press.

	Price / quantity	Quantity / panel	Price / Panel	Price / Kovivol (7)
<b>Coating</b> [BioPin clear lacquer]	€16,96 / 0.75L <sup>1</sup>	75-85 mL / m <sup>2</sup> <sup>1</sup> 450-510 mL of coating / panel	€12	€2,93
<b>Laminate</b> [CB1]	+ - €10 / laminate	2 laminates / panel	€20	€4,87
<b>Adhesive</b> [BioImpact Canect]	€300 / tank	240 m <sup>2</sup> / tank 6m <sup>2</sup> / panel	€7,50	€1,80
<b>Core</b> [no-added formaldehyde]			€60,10 / panel <sup>2</sup>	€14,65
<b>Kovivol</b>				<b>€24,25</b>

Table 16. Price calculation.

<sup>1</sup> (BioHome(a), n.d.)

<sup>2</sup> Based on the assumption it will be half the price of 18mm Maiburg no-added formaldehyde (E0) Panguaneta plywood with FSC certification (Maiburg(b), 2021).

## 6.3 Assessment

The main challenge for the design of the condiment organizer consisted of implementing the optimized furniture panel and to have an appearance similar to the other coffee corner products. The design is based on panel material. Although the implemented panel is not precisely the one as proposed in Chapter 5, it is a thin version of a combination between two of the (seriously) considered panel concepts. As for the appearance requirement, Kovivol resembles the rectangularity of the coffee station by its use of panels, and the natural shapes by the engraved patterns and small outer line varieties (figure 72; figure 73). The color scheme is similar, but not

an exact match to that of the coffee station as the parts are laser cut, causing the sides to be charred (figure 74). The CNC-milled edges of the current panels clearly show the plies, whereas the proposed optimized panel is entirely covered in CB1 colored material. Luckily, the laser cut charring provides an aesthetically pleasing effect, as the reduced contrast ensures the focus to be on the laminate instead of the light-colored edges. To assess the completion of the second project challenge, the designed and prototyped concept of the condiment organizer is evaluated based on the set requirements (table 17).



Figure 72. Natural shapes of engravements (left and middle), similar to coffee station (right).



Figure 73. Rectangular shapes of the condiment organizer (left and middle), similar to coffee station (right).



Figure 74. The sides of the laser cut condiment organizer (left), with an edge band edge (middle) and CNC-milled (right).











Principle	Nr.	The condiment organizer ...	Kovivol
Desirability	[D1]	... has the same form language as the coffee station and coffee machine fronts.	 <p>Yes, but not fully because of the charred edges.</p>
	[D2]	... is able to orient and display the following condiments: tea bags, stirring sticks, milk cups and sugar sachets.	 <p>Yes, but not fully because a second iteration is required.</p>
	[D3]	... is flexible and allow for changes in condiment brand variations.	 <p>Yes, the fronts are replaceable up to preference. The wall dividers can be placed in multiple spots.</p>
	[D4]	... contains visual communication to represent its sustainable character.	 <p>Yes, for the laminate. No, for the other materials.</p>
	[D5]	... is accessible to all types of users, including but not limited to left and right-handed users and users with poor eyesight.	 <p>Yes, the design is symmetrical, and condiments are referred to with white paint.</p>
Feasibility	[F1]	.. is manufacturable with the facilities made available by their furniture manufacturer.	 <p>Laser cut facility required.</p>
Viability	[V1]	... does not use panel materials exceeding a (total) cost of €20.	 <p>No, maximum material costs are around €25 for a 7-compartment design. The one containing 3 or 5-compartment use less material and will be cheaper.</p>
Sustainability	[S1]	... implements the optimized panel.	 <p>Not the core, nor the edge band is applied in the design.</p>
	[S2]	... is modular to allow for flexibility in amount of condiment compartments, avoiding unnecessary material use	 <p>Yes, three different back frame options and condiment specific fronts.</p>
	[S3]	... uses its material efficiently, using as little material as possible.	 <p>Yes, all parts are efficiently arranged in the laser cut file.</p>
<b>Total</b>			<b>5</b>

Table 17. Requirements for the 'Kovivol' condiment organizer (design) evaluated



## 6.4 Proposal

Kovivol is sustainable and customizable condiment organizer, with an appearance that corresponds well to the other CoffeeBased coffee products (figure 75). The back frame is pre-assembled and the fronts can be selected based on the user's preference, providing the

user the option to change their set up (figure 76). Although the design allows for flexible compartment application, a standard 7-compartment assigning is recommended, with room for CoffeeBased coffee cups (2x), tea (2x), sugar, milk and stirring sticks (figure 77).

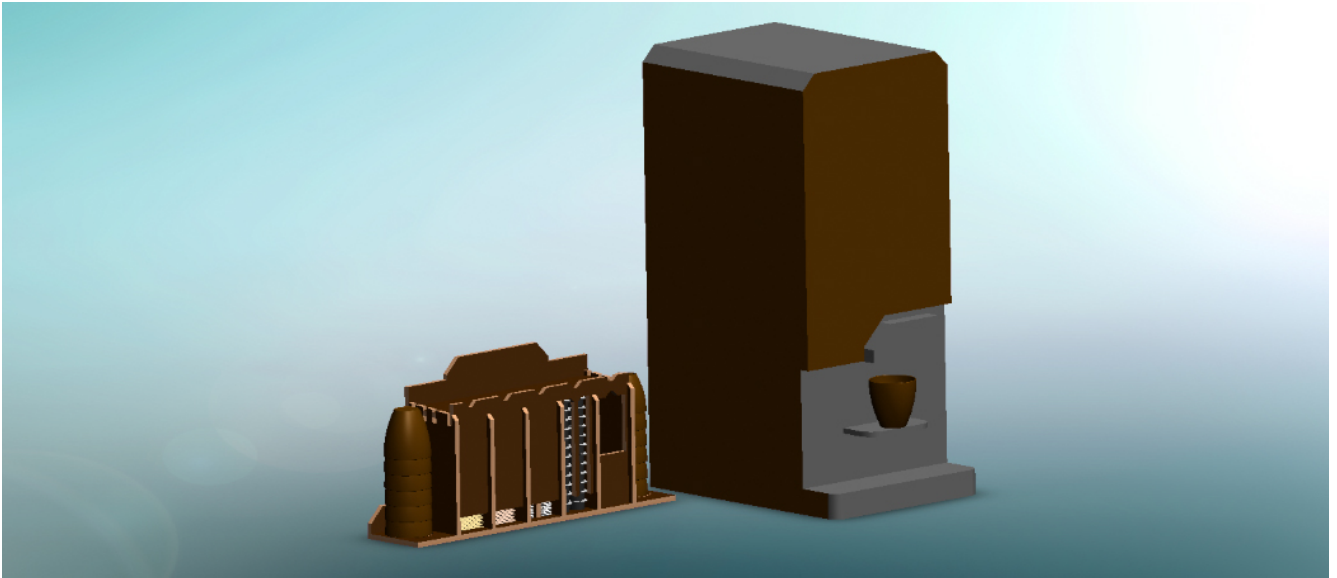


Figure 75. SolidWorks model of Kovivol next to the coffee machine with a CoffeeBased front.

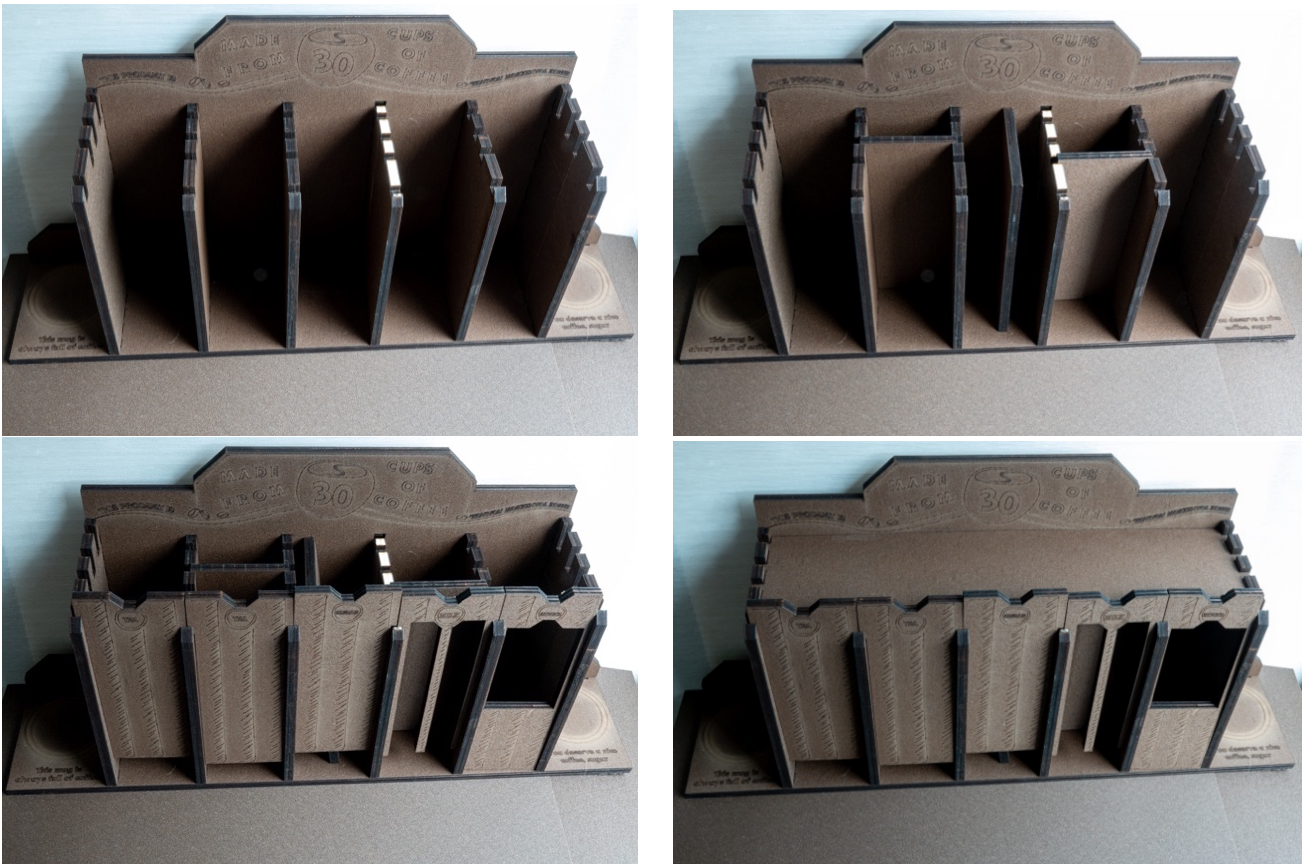


Figure 76. Kovivol 7-compartment standard edition assembly steps: pre-assembled (top left), added compartment dividers (top right), added fronts (bottom left), added top panel (bottom right)



Figure 77. Kovivol 7-compartment standard edition.

Material- and product manufacturer CoffeeBased upcycles SCG from a low-valued waste material into a state suitable as biobased plastic filler (figure 83). Under the slogan “Kovivol: mokkenvol koffie!” (translation from Dutch: “Kovivol: full of coffee!”), this condiment organizer poses as yet another example of a high valued

product (figure 78). Every time corporations buy the Kovivol condiment organizer, they help sustain the upcycling system. Per 7-compartment Kovivol design, the coffee waste accumulated from 44 cups of coffee is saved from incineration (figure 79).



Figure 78. Kovivol logo



Figure 79. Upcycling: 44 cups of coffee, to SCG, to 0.73 m<sup>2</sup> panel, to a 7-compartment Kovivol.







CUPS

OF

COFFEE

MOKKENVOL KOFFIE

MILK

STICKS



## CHAPTER 7

# **Conclusions & Recommendations**

## 7.1 Conclusions

Material- and product manufacturer CoffeeBased produces laminates with aesthetic and sustainable value, that are used to laminate furniture panels. Presently, when the panels are used in the desired user context, the coffee corner, the aesthetic value of the laminate reduces as it discolors and distorts. Apart from this problem, the sustainable value of the panel was questionable as all components, except for the laminate, were not selected based on their sustainable character. This includes the core, adhesives and coating. These two optimization possibilities led to the **first** project challenge: optimize the sustainable value and context resistance of the panel. Key requirements during optimization are that the panel remains manufacturable by the current furniture maker, is acceptable to end users and suits the resources of CoffeeBased.

Market research was done to find available sustainable alternatives for all components. The most promising options were assessed by their theoretical improvement, and physical tests helped confirm their feasibility. Four panel concepts were presented, each focusing on optimization of different aspects. To decide on the final concept, a trade-off had to be made between either fitting all requirements or excelling in sustainability. The latter was selected as it suits this design challenge better (figure 80). The concept proposes to keep the CB1 laminate, while all other components are to be replaced by the following: EcoBoard by FiberPlast as core, BiolImpact by Canect as adhesive, transparent lacquer by BioPin as coating. Since the exposed sides of the EcoBoard core are not aesthetically pleasing, the development and addition of a CB1 laminate edge band is suggested. Both the coating and the edge band help enhance the panel's appearance. The sustainable character of the panel has increased compared to the original panel. Its proposed components are locally produced, and the panel holds approximately 83% more waste and 12% more biobased materials, whilst reducing the ingredients that could emit VOCs by 1%.

The **second** design challenge was to design a condiment organizer proving the optimized panel and to expand the offer of coffee products by CoffeeBased. The design has corresponding aesthetics with the other coffee corner products and implements condiment specific orientation.

To design a user-friendly condiment organizer, brainstorm sessions were held to determine user wishes. By clustering the generated ideas onto axes and presenting this to the client, a preference for a more uniform rectangular design with compartments came forth. Four main ideas were sketched and again presented to the client which led to the conceptualization of the most promising one. The chosen concept is to deliver a pre-assembled back frame for a condiment organizer of three, five or seven compartments (figure 81). A standard selection of condiment compartment fronts is suggested, but the user may select a different combination to their preference. The final design does not incorporate the proposed optimized panel as was desired. This, because a box joint connection was considered more suitable which cannot be made using CNC milling. Consequently, with laser cutting as the new manufacturing method, EcoBoard with its resin and open structure could not be used. Also, the proposed edge band is not implemented because of the box joint connections, to reduce risk of delamination. A no-added formaldehyde core from one of the alternative panel concepts was selected instead. The transparent lacquer will still be applied to all sides of the panel to protect it properly in the desired user context. As for aesthetic resemblance, Kovivol's contour and laminate engravements corresponds with the appearance of both the coffee machine fronts as the coffee station.

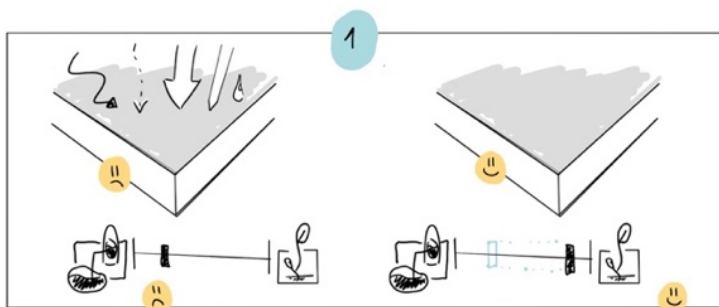


Figure 80. Project challenge 1 "optimize panel" (left) and result (right).



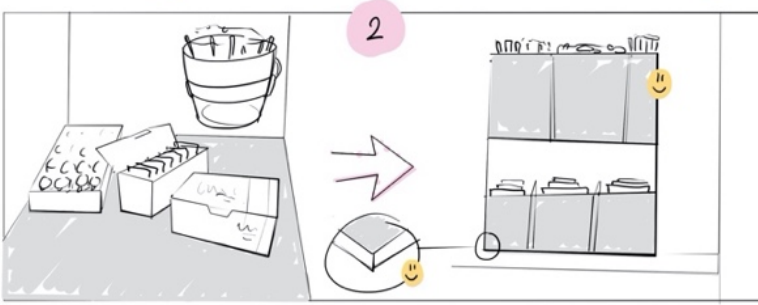


Figure 81. Project challenge 2 “design condiment organizer” (left) and result (right).

## 7.2 Recommendations

For the first project challenge concerning the optimization of the panel, the following actions are recommended to CoffeeBased:

### **Implement proposed panel**

Start developing an edge band using the CB1 material. Replace the current plywood core with EcoBoard, adhesive with BioImpact and coating with BioPin. This will enhance the sustainable value of the panel making it acceptable to promote as a sustainable furniture panel.

### **Develop CB2 laminate**

Start with the development of a laminate using CB2 material, because the CB1 material does not have the properties required to function as laminate on its own. CB2 on the other hand is predicted to provide resistance to the most pressing sources of impact. When developed, it is necessary to make sure the CB2 laminate can be adhered, which a surface free energy measurement will indicate. Arends Surface Treatments has offered to do this test on sight, assessing if a corona treatment would improve adherence. If so, it is recommended to find a panel manufacturer that owns corona treatment equipment, as the purchase price is around €100.000.

For the second project challenge concerning the development of a condiment organizer, the following actions are recommended to CoffeeBased:

### **Manufacture condiment designer**

Start with developing the panels as suggested for the design of the condiment organizer: double laminated 8mm no-added formaldehyde plywood with the same lacquer and adhesive as the optimized panel. To manufacture the proposed condiment organizer design, a connection with a laser cut facility needs to be established.

### **Iterate to a condiment organizer 2.0**

The realization of the concept prototype brought up some points of improvement, therefore it is recommended to continue iterating as the prototype did not function properly. The problems concerned front stabilization, deepening of the cup groove, changing the height of the condiment grab gap and the slit cover in the stirring stick compartment, and improving the visuals communicated on the surface. See Appendix L for pictures of the encountered problems.

### **Exclude coffee cups**

Besides the suggested improvements, it is proposed to exclude the coffee cup spots from the design of the condiment organizer, for hygiene reasons. A more hygienic alternative would be to alter the integrated cup dispenser inside the coffee stations to hold the CoffeeBased coffee cups.





nie van de Velde

jaar. Een moeilijk jaar. Waar we elkaar soms moeten helpen. Ook bij De Havenloods. We kunnen niet met de mensen om ons heen, de mensen kunnen rekenen. Bij het maken van de krant, kunnen rekenen. Bij het maken van de krant, kunnen rekenen. Bij het maken van de krant, kunnen rekenen.



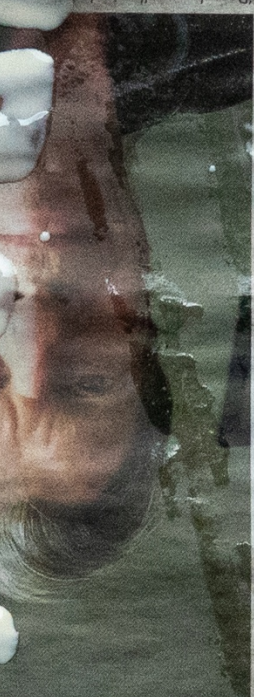
ontmoetingen, zoals Britte Kramer, was 2020 niet zo makkelijk. Probeer thuis maar eens een 'groot' gesprek te hebben! Uiter aard vond ze er wat op. Je kon wandelen, dat deed meer mensen. En als je al die mensen deed je roepen ze vanzelf iets terug. De beste kind...

even een recente foto, zonder nog iets ontdekt. "Ik stuur, dus, voor Peter. Want hij heeft Een lezaam jaarje, maar schuld in het Duits. 83 dagen lang. Ik weet nu wat dag heb ik drie kwart...

in het Duits te kunnen. Elke doen. Dat hoop ik straks ook jaar meer stedsrondeleidingen man! Verder wil ik volgende gevolg bij werkplaats. Buur- kan maken, ik heb tinnemies dat ik nu zelf kastjes en stoelen taal bijbreng. "Ik ben ook trots nieuwkomers de Nederlandse een verhaal vertelt, en hoe je volgt. Over hoe je het beste cursussen en workshops geeft. Verder heeft Peter 2020 ge- staan en veilig gev...

zo bekende enthousiasme. "Zacht hij met het van hem dan gewoon met mijn 'Photo-Verlagger', spelen, maar vloggen voor Open Rotterdam. nu hij gevraagd is om te gaan Toch blijft Willem blij. Zeker "men..." maar mijn ouders niet doet wel iets met je. Die drie verlichte zonen kan ik best is alle afstandelijkheid. Dat Wat ik wel echt moeilijk vind aan wat op mijn pad komt vrouw in haar bedrijf en pak...

Wat wilt u? Zo help ik ook mijn... als je iets kunt doen, doe dan gewoon met mijn 'Photo-Verlagger', spelen, maar vloggen voor Open Rotterdam. nu hij gevraagd is om te gaan Toch blijft Willem blij. Zeker "men..." maar mijn ouders niet doet wel iets met je. Die drie verlichte zonen kan ik best is alle afstandelijkheid. Dat Wat ik wel echt moeilijk vind aan wat op mijn pad komt vrouw in haar bedrijf en pak...



deze pandemie hebben. Tot komend jaar met al die maanden tot 88 jaar samen te brengen. Maar het blijft een antwoord om mensen van 8 deijk bleek het toch niet ver- bij Weelde aan toe. Uitein- geregeld, tot aan de locale dit jaar niet door. Alles was ROTTERDAM - Dat feest ging komt! ook echt dat grote feest passen, het jaar waarin nu om die volgende jaar toe te kijkt er (zonder bril!) naar uit lopen rofjaar gebruikt om Peter van Heemst heeft afge-

Rotterdam - Dat feest ging komt! ook echt dat grote feest passen, het jaar waarin nu om die volgende jaar toe te kijkt er (zonder bril!) naar uit lopen rofjaar gebruikt om Peter van Heemst heeft afge-



morgens gada had ge... hoeveel goeds zo'n simpel, gedachteloos groetje... vallig plaatste Arie Boomsma vlak daarna eenzelfde... op Instagram: "Groet iedereen die je tegenkomt: Glimlach door Rotterdam, want dat is op los. In de meeste gevallen groeten mensen ten... genaam verrast. Je kunt iemands dag ermee... en een ander doorbreken. En je komt zond... emming aan met een glimlach op je gez... ers van de Week Richard Groenendijk e...

ijkt dankba naar 2021, zonder

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CHAPTER 8

# **Discussion & Reflection**

## 8.1 Discussion

### Project validity

There are two factors that could call into question the validity of this project. Firstly, during this project a lot of tests were necessary to validate assumptions, make assessments or test requirements. Because no professional test equipment was available, accessible alternatives had to be thought of. Therefore, the credibility of some of the results could be questioned. The following aspects could have influenced these results.

1) Inconsistency in photo set-up and application of coatings and adhesives prohibited optimal comparison. Therefore, the credibility of some of the results could be questioned, for impact estimations see Appendix M. A more structured plan and fixed set-up could resolve this problem.

2) Dysfunctional test equipment led to certain tests providing incorrect and therefore unusable results. Since these test results were completely rejected and therefore no conclusions were based on them, the impact of this aspect is estimated to be 0%. Future test equipment should always be pre-tested to avoid this problem.

The second factor regards the available information to use in assessments and thereby the validity of the drawn conclusions. A big part of the process to solve the first project challenge involved market research into sustainable alternative materials for the furniture panel. For this, off-the-shelf products were researched and compared. Due to a lack of public information regarding product ingredients and their proportions, the produced assessments and estimations could be inaccurate. In this project other sources, such as papers, were consulted to still provide a substantiated estimation to work with. Unfortunately, these sometimes contradicted each other. Full transparency in product ingredients will probably never be possible, as this would lead to competitors misusing this public information and inevitably producers losing business. Some insight into the sustainable character of products, while maintaining the producer's confidentiality, can be achieved by way of certification. Unfortunately, not all producers use certificates, as acquiring these costs money. Besides, certificates are not universal and therefore still makes comparing products difficult.

### Suggested follow-up research

#### 1) Keep an eye out for development

Until the panel reaches a 100% waste and 100% biobased content without any ingredients containing VOCs, the panel can improve its sustainability. Luckily, material- and product developers are also continuously improving and evolving to keep up with the rising consumer demand for eco-friendly products. For instance, in the near future, Orineo will make their 100% biobased binding agent available for industrial application (Orineo, n.d.). This would reduce any constraints on adhesive use, thus making multilayered cores a more sustainable option. Another example is ECOR, that could be used on the outer planar sides of a cardboard honeycomb to obtain a composite sandwich core (figure 82). The panel concept could also keep improving, depending on the ongoing sustainable developments. If CB2 laminate development is initiated, it can be wise to keep looking for suitable primers as cheap substitute of the corona treatment equipment, like those offered by Auro (2021(c)).

#### 2) Consider different end-of-life policies

CoffeeBased could put a spotlight on the current Dutch waste practices and its incineration of materials that could still be valuable. This, by proposing a better alternative that suits the resources at hand. For instance, an end-of-life return policy. As soon as the panels would be discarded, they can be returned instead of transported to be incinerated. Delamination could help retrieve the most value from all components, this is why CB2 with its higher melting temperature would be suggested to be used.

#### 3) Consider different cores

The CB2 material can be processed in plastic recycling facilities, which means that when combined with a recycled plastic core, the entire panel could attempt a 100% recycling rate. The laminate can be welded on top, deeming the adhesives unnecessary just like the Resysta NoWood core in panel concept 4. This is why research into recycled plastic cores is suggested. Choosing an unconventional material for the core brings some considerations, a few of which are described in Appendix N.



Figure 82. Example of multilayered core, including two sheets of triplex wrapping a cardboard honeycomb layer.



## 8.2 Reflection

This project represents the end of my student career, providing only a limited amount of time to develop design competences within the academic setting of the TU Delft (at least for now). Therefore, to make the most of these last few months, five personal goals were selected to try to achieve.

The first goal was to stop overthinking problems, by avoiding endless research but instead start prototyping. One can examine papers for hours or receive test results within minutes. This is not only a quicker way to determine results, but also very educational and fun. I worked on prototyping in both an amateurish setting as well as a professional one. The first one was on my well-ventilated balcony, using available products such as a laundry mangler, table extruder and nail polish UV lamp. This amateurish way of prototyping stimulated my creativity in application of available everyday products. The professional prototyping was facilitated by the faculty of Industrial Design Engineering (IDE), which only a few months into my thesis project, allowed me the privilege of using their prototyping areas (PMB and Applied Labs) for two days a week. Providing the opportunity to use facilities such as laser cutting, milling, sandblasting and sheet pressing (figure 83). This professional way of prototyping gave me a better feeling for the use of materials (figure 84).

Secondly, my aim was to start asking for help sooner rather than later. As a student, I should not be ignorant of certain topics, though it does often feel like admitting ignorance. The weekly- and monthly meetings with my mentor and chair made it easier to ask them questions, in order to learn from their years of experience in the design field. Also VerdraaidGoed, the overarching company of CoffeeBased, had a check-up meeting

scheduled every week with all its employees, interns and graduate students. This was perfect to keep tabs on all developments inside the company and a good time to request meetings with employees. It has also been eye opening to see how willing people are to help: salesmen, manufacturers and sustainable consultants. Normally, the barrier of having to initiate contact in order to receive help, would keep me from asking. Luckily, all these planned sessions provided ample opportunities to ask for help in a more casual setting. Therefore, during this project I finally managed to ask for help on a regular basis, instead of endlessly collecting questions and eventually feeling overwhelmed.

The aim of the third goal was to get better at planning, to avoid my usual end-of-project stress. Time management has always been a struggle, and with an important project like this, it was considered even more crucial to optimally use my time. During this project a variety of planning tools were tried out, including post-its, Miro, Word-documents, Excel-documents, Asana and above all: IDE's signature product: dummy's (sketchbooks). Unfortunately, 'the more the merrier' did not turn out to apply to planning tools. The lack of overview and inconsistent use of tools led to a lack of insight into the planning and process. Apart from finding the perfect planning tool, a good action plan also appeared essential to master time management. By (apparently) not creating an airtight project scope at the start, the focus of the project shifted multiple times by my aspiring attempt to get familiar with all related topics. Although my planning skills did not turn out perfect during this project, I did learn that choosing just one planning tool in combination with a carefully laid out plan and well-defined scope are imperative for efficient time management.



Figure 83. Pictures of me milling in PMB, hot pressing at Applied Labs and extruding at home.



Figure 84. Collection of material samples accessible for testing (left) and their preparation before use (right).

The fourth goal was to limit the experienced stress to a healthy level. Especially due to the COVID-19 restrictions it became evident that relaxing activities for at home were needed to maintain a healthy mind. Assisting activities, implementable between tasks, included small walks, yoga exercises and drinking coffee with designated study buddies. Another more useful way to stay relaxed is by alternate serious tasks with more fun ones, like painting a mock-up coffee machine or material exploration with the table extruder (figure 85).

Lastly, to grow as a sustainable designer, it was considered valuable to become more familiar with the

semi uncharted territory of bioeconomy jargon and methods. I can proudly say that this goal was achieved, as I researched any unknown term and by asking questions whenever anything was unclear (as per personal goal 2).

All in all, I think during the execution of this thesis, I made incredible improvements on a personal level. Luckily, this project was a great way to combine my passion for design with my interest in sustainability. I am glad I was given the opportunity to complete my (almost) seven years of studying with such a fitting quest.



Figure 85. Fun tasks to reduce stress level: a coffee machine mock-up (left), material exploration using a table extruder (middle) and its result (right).







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