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Appendix A: Project brief

The brief has been detailed in a separate document

Appendix B: ESPR DPP data requirements

The ESPR regulation (REGULATION (EU) 2024/1781) describes the EU's ecodesign requirements for sustainable products. Part of these requirements are the mandate of the digital products passport (DPP) through delegated acts. Within this DPP, the regulation assigns so called "product parameters", that form the categories of data that must be addressed. As seen in figure x, the product parameters (column 2) can be expressed through various attributes (column 3), of which the regulation gives examples. To make sense of the product parameters, this thesis colour coded them into categories: **Product attributes**, **material circularity**, **circular potential**, **environmental impact**.

Product parameters expressed in ANNEX I of the ESPR regulation (2024):

	Product parameter	Expressed through	Category
a	Durability and reliability of the product	product's guaranteed lifetime, technical lifetime, mean time between failures, indication of real use information on the product, resistance to stresses or ageing mechanisms.	Product attributes
b	Ease of repair and maintenance	characteristics, availability, delivery time and affordability of spare parts, modularity, compatibility with commonly available tools, etc...	circular ability
c	Ease of upgrading, reuse, remanufacturing and refurbishment	number of materials and components used, use of standard components, use of component and material coding standards for the identification of components and materials, number and complexity of processes and tools needed, etc...	circular ability
d	Design for recycling, ease and quality of recycling	Use of easily recyclable materials, safe, easy and non-destructive access to recyclable components and materials or components and materials containing hazardous substances and material composition and homogeneity, etc...	circular ability
e	Avoidance of technical solutions detrimental to reuse, upgrading, repair, maintenance, refurbishment, remanufacturing and recycling of products and components	-	circular ability

f	[...] Use of substances of concern	substances of concern, on their own, as constituents of substances or in mixtures, during the production process of products, or leading to their presence in products.	material circularity
g	Use or consumption of energy, water and other resources	one or more life cycle stages of the product, including the effect of physical factors or software and firmware updates on product efficiency and including the impact on deforestation;	environmental impact
h	Use or content of recycled materials and recovery of materials, including critical raw materials	-	material circularity
i	Use or content of sustainable renewable materials;	-	material circularity
j	Weight and volume of the product and its packaging [...]		Product attributes
k	Incorporation of used components		material circularity
l	[...] Consumables needed for proper use and maintenance	quantity, characteristics and availability [...],inter alia, through yield, technical lifetime, ability to reuse, repair, and remanufacture, mass-resource efficiency, and interoperability;	material circularity
m	The environmental footprint of the product	quantification, in accordance with the applicable delegated act, of a product's life cycle environmental impacts, whether in relation to one or more environmental impact categories or an aggregated set of impact categories;	environmental impact
n	The carbon footprint of the product;		environmental impact
o	The material footprint of the product		environmental impact
p	Microplastic and nanoplastic release		environmental impact
q	Emissions to air, water or soil		environmental impact
r	Amounts of waste generated	plastic waste and packaging waste and their ease of reuse, and amounts of hazardous waste generated	environmental impact

s	Functional performance and conditions for use	ability to perform its intended use, precautions for use, skills required and compatibility with other products or systems	Product attributes
t	Lightweight design	reduction of material consumption, load- and stress-optimisation of structures, integration of functions within the material or into a single product component, use of lower density or high-strength materials, etc...	Product attributes

Appendix C: Cradle to cradle and digital product passports

Because of the thesis client, the circular economy (CE) is defined through the cradle to cradle (C2C) design philosophy. This model, founded professor Micheal Braungart, is widely used in literature and industry (sustainability) practice. Digital product passports (a.k.a materials passports) are introduced within C2C as a supporting role.

Everything is a resource for something else

The C2C model, inspired by nature's regenerative processes, aims for a closed loop system, where used materials are regenerated into new materials through one of two routes: In the biological cycle, these "nutrients" grow and break down through the natural ecosystems. In the technical cycle, material is reused without loss of quality through human cycling processes.

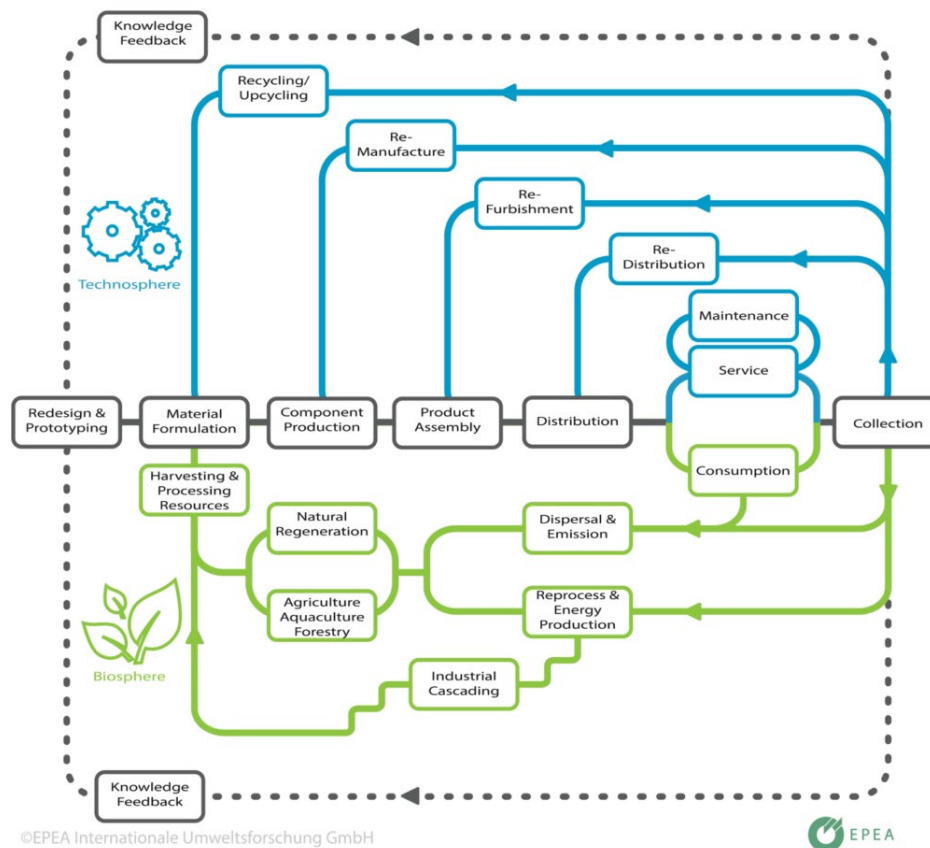


Image: Material flows in Technosphere (blue) and Biosphere (green)

Eco effectiveness vs eco efficiency

C2C suggests that focussing on doing “less bad” for the environment does not fundamentally solve sustainability issues, it just postpones them. C2C introduces the idea of eco-effectiveness: the ability to provide value for the environment with our products, for example by supporting healthy living environments, clean air or water, or diversity. If we apply eco effectiveness in a business context, ecology, equity and economy come together to support one another. C2C argues that these elements don’t contradict each other, but go hand in. (*illustrated in figure X*)

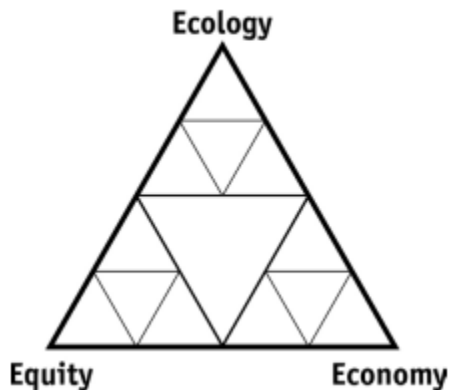


Figure x: Fractal ecology triangle from the cradle-to-cradle design framework

Role of digital product passports in C2C

For material flows, DPPs support in:

- Making materials regenerative *by design*
- Facilitate the cycling steps in the Biosphere and Technosphere

For eco-effectiveness, DPPs support in:

- Conveying the *quality* of defined material, to promote the right qualitative measures.
- Supporting ecology, equity and economy

Appendix D: Opportunity cards

Being able to make decisions faster/be more resilient

Knowing more about your product, competitor, market and customer allows you to respond better to the changes around you. You are more resilient as an organization.

Digital Product Passports- Opportunity Cards



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Opportunity Card

Being able to make decisions faster/be more resilient

Connecting to a widely accepted definition of circularity

There are 144 definitions of circularity. A good DPP format is vital to have the right scope of circularity in view and to get your story right.

Digital Product Passports- Opportunity Cards



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Opportunity Card

Connecting to a widely accepted definition of circularity

Start on time to avoid costs for ESPR legislation

Collecting all the necessary data, setting up IT infrastructure and iterating into a working DPP is a big job. It is better to have enough time for this, in order not to face (expensive) surprises later.

Digital Product Passports- Opportunity Cards



"Waiting also carries risks. Before you know it, you're too late"
- Manufacturer (about DPPs)

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Opportunity Card

Start on time to avoid costs for ESPR legislation

Setting up new products

DPPs give the opportunity to better understand the consumer and usage of the current product range. From this, new propositions can emerge for products or by-products.

Digital Product Passports- Opportunity Cards



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Opportunity Card

Setting up new products

Provide/support recycling, repair, repurposing and remanufacturing services

The DPP makes it easier to position circular services. This can provide additional revenue, customer loyalty, and sustainability image.

Digital Product Passports - Opportunity Cards



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Opportunity Card

Provide/support recycling, repair, repurposing and remanufacturing services

Establish and support circular business case

Collective DPP implementation is expected to be beneficial for companies already paying attention to circularity. Many of the data barriers that made circularity difficult will be solved.

Digital Product Passports - Opportunity Cards



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Opportunity Card

Establish and support circular business case

Organize and share sustainability information better

Maak informatie overzichtelijk en makkelijk beschikbaar, zowel intern als extern. Dit verbetert samenwerking en versterkt je positie als duurzame producent.

Digital Product Passports - Opportunity Cards



"Now we have to send a separate document for everyone with just different information." - Manufacturer

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Opportunity Card

Organize and share sustainability information better

Stand out from competitors by being the first with a DPP in the industry

Your customers are currently being fleeced by "sustainable" products. If you offer a DPP before the rest of the market does, you stand out. You can educate your customers and investors on the subject when they ask about it. All of this is positive for your image.

Digital Product Passports - Opportunity Cards



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Opportunity Card

Stand out from competitors by being the first with a DPP in the industry

Keeping in touch after the sale

The DPP provides a point of communication after delivery. Good after-sales service strengthens customer relationships and increases the likelihood of repeat purchases.

Digital Product Passports - Opportunity Cards



"Through our DPP, the user can register the product to their account. If they want to recycle it, they are referred to our second-hand platform." - Manufacturer

2

Opportunity Card

Keeping in touch after the sale

(Re)designing current products smarter and more sustainable

The DPP helps to collect more data about the product and materials. The DPP thus provides information for further improvement. Making a DPP also gives a clear picture of where the product can be improved with regard to circularity.

Digital Product Passports - Opportunity Cards



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Opportunity Card

(Re)designing current products smarter and more sustainable

Reducing risks in the supply chain

Avoid reputation damage and legal problems: make sure you understand where your materials come from and how they were produced.

Digital Product Passports - Opportunity Cards



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Opportunity Card

Reducing risks in the supply chain

Spend less time on reporting

Automate or simplify the collection and sharing of circularity information for customers and legislation.

Digital Product Passports - Opportunity Cards



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Opportunity Card

Spend less time on reporting

Appendix E: Interview guide

Interview Structure

- Format: In-person & virtual (Microsoft teams video call)
- Estimated Duration: 60 mins per interview
- Recording Method: Audio recording & notes
- Language: dutch (NL) and English (EN)

The interview structure follows the theory of the “path to expression” from Convivial Toolbox (2012) to determine question order. This helps to sensitize the interviewee to recall thoughts and experiences more with more detail, leading to better insights.

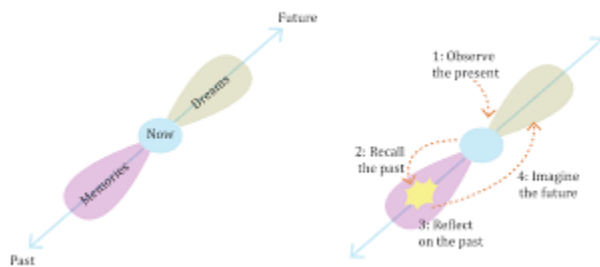


Figure x: Path to expression (Convivial toolbox, 2012)

The main research question is:

Main question

The main research question is:

“How do companies regard the value of digital product passports?”

For example, companies could describe this in terms of opportunities, challenges, business value, potential or risks.

To deepen the answer, we ask the adjacent question:

“What is the relevant context to understand *why* they view digital product passports in this manner?”

For example, companies could describe this in terms of relevance to their own ambitions, motivations, activities, etc.

Interview questions

Introduction to the research

NL: "We merken dat bedrijven in ons netwerk het lastig vinden om strategisch voordeel te behalen met DPP's. We hebben vernomen dat jullie al significante stappen hebben gezet.

het doel van dit gesprek is om beter te begrijpen wat de toegevoegde waarde van het gebruik van een productpaspoort kan zijn voor een bedrijf. "

EN: "We find that companies in our network find it difficult to gain strategic advantage with DPPs. We learned that you have already made significant strides.

the purpose of this conversation is to better understand what the added value of using a product passport can be for a company."

Introduction questions

NL

Wat betekent een DPP voor u? Wat heeft u erover gehoord?

Kun je mij in je eigen woorden vertellen wat een DPP is?

Wat is jullie DPP ervaring?

Hoe worden DPPs op dit moment in de organisatie gebruikt?

EN

What does a DPP mean to you? What have you heard about it?

Can you tell me in your own words what a DPP is?

What is your DPP experience?

How are DPPs currently being used in the organization?

Core research

NL

Kunt mij meenemen in hoe het besluit proces is verlopen om een DPP op te stellen?

Zien jullie strategische voordelen in het gebruik van DPP's? zie jullie nadelen?

Hoe verwacht je dat de situatie zal uitspelen?

Hoe zou de ideaalsituatie zich uitspelen? Wat zou je er graag in willen zien?

Welke ambities zouden jullie met het gebruik van DPP's willen vervullen? en hoe zouden deze het best vervuld kunnen worden?

EN

Can you tell me about the decision process to create a DPP?

Do you see strategic advantages in using DPPs? do you see disadvantages?

How do you expect the situation to play out?

How would the ideal situation play out? What would you like to see in it?

What ambitions would you like to fulfill with the use of DPPs? and how would they best be fulfilled?

Clarification & wrap up

NL

Heb ik een belangrijk onderdeel gemist?

Heeft u nog vragen voor mij?

EN

Did I miss an important part?

Do you have any questions for me?

Next steps

- Clarify fact that this interview will be used in graduation thesis findings
- Depending on discussion: sending information on DPPs, contacting other mentioned stakeholders

Ethical considerations

- Ethical Considerations: Prior to the meeting, participants are asked to sign a consent form. Responses are treated as confidential and kept on an internal harddrive.

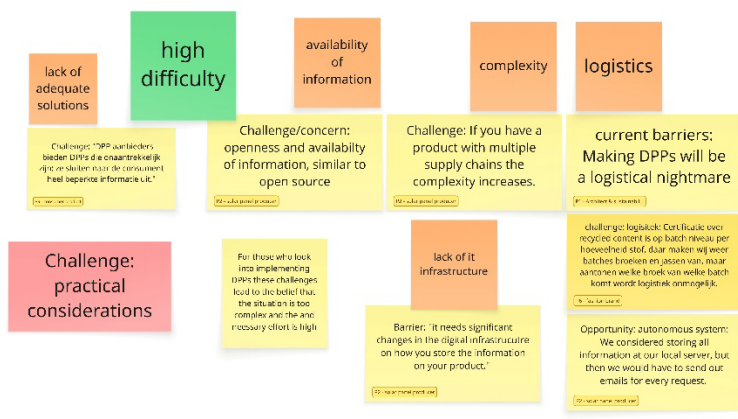
Appendix F: Thematic analysis of interviews

Chapter 3 describes the challenges and opportunities that resulted from the interview process in chapter 3. The following visuals present the thematic clusters that led to these findings.

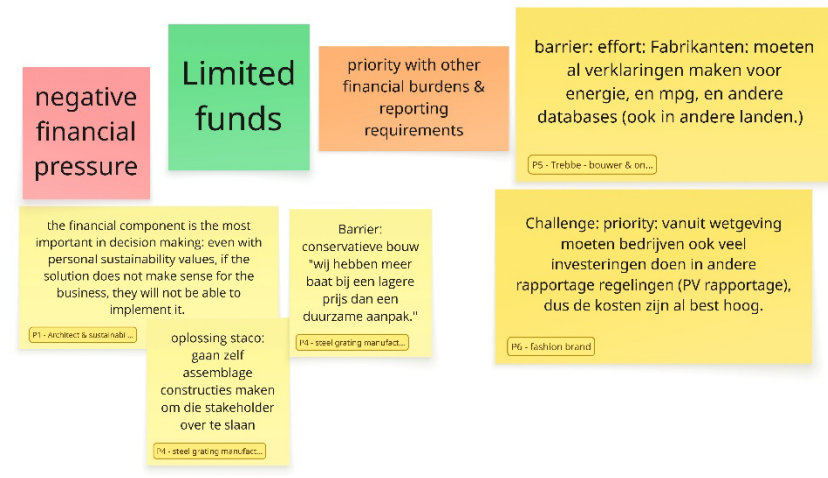
Core challenges



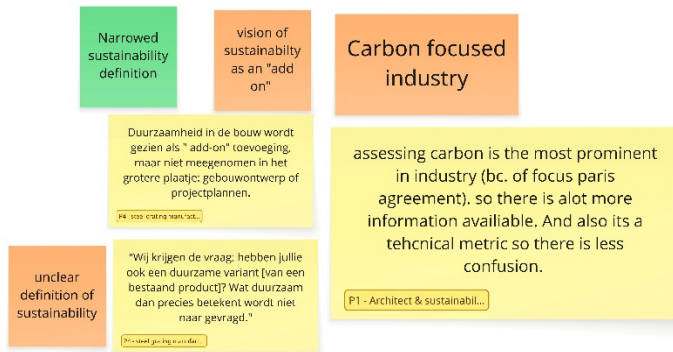
costs



Difficulty



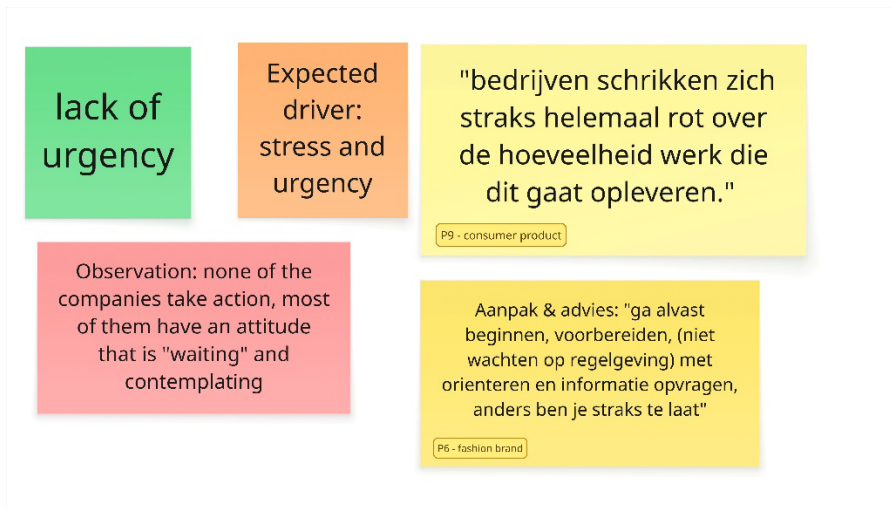
Limited funds



Narrowed sustainability definition



Supplier coordination



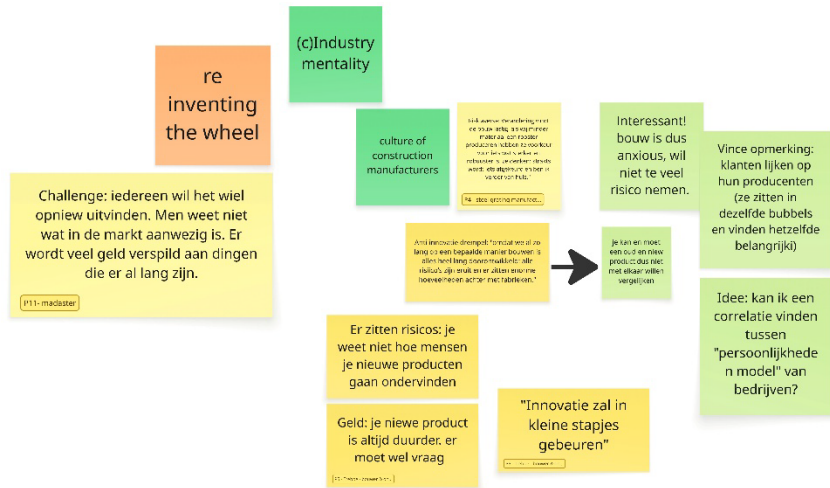
Lack of urgency



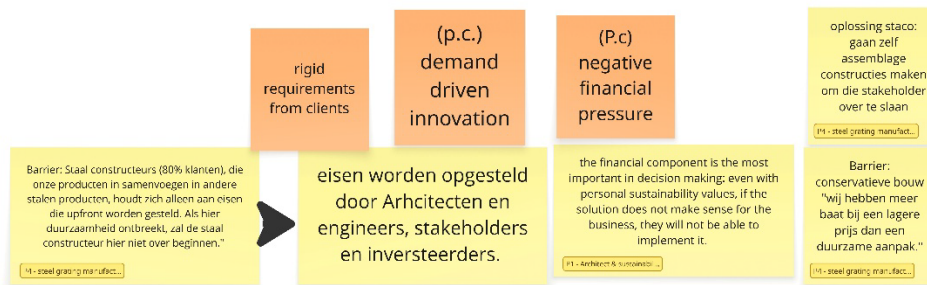
Uncertainty in future

Unclear rewards/opportunities

Peripheral challenges

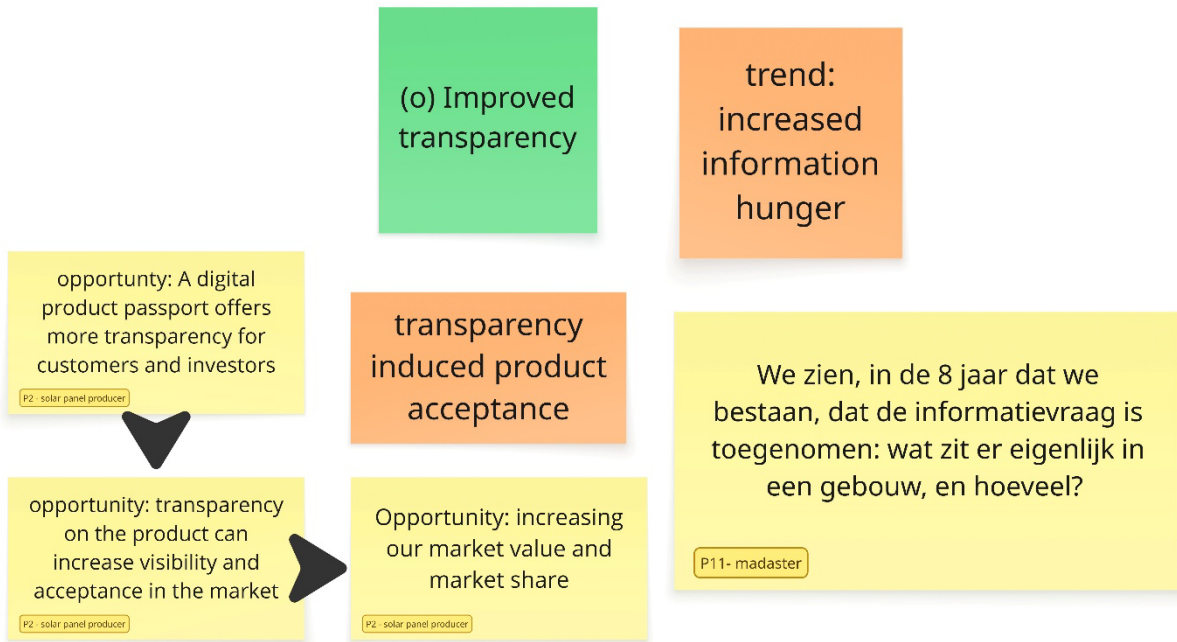


Industry mentality



Innovations considerations

Opportunities to DPP implementation



Improved transparency



Improved client relationship



Streamline external communication + internal processes

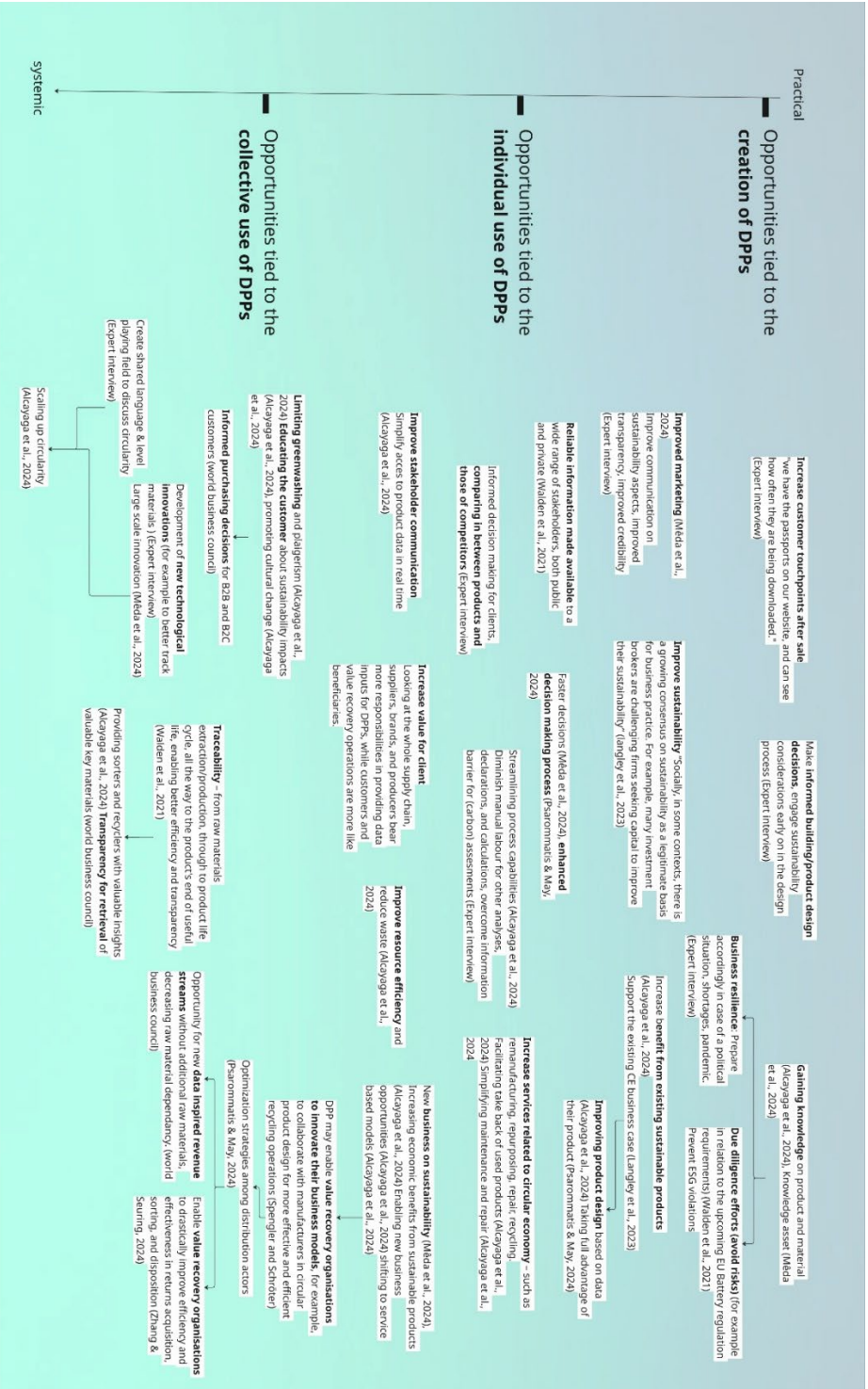


Normalisation of circularity



Alignment with intrinsic value

Appendix G: Overview of opportunity selection



Appendix H: Material results from co-creation workshops

Workshop session A: Solar panel manufacturer

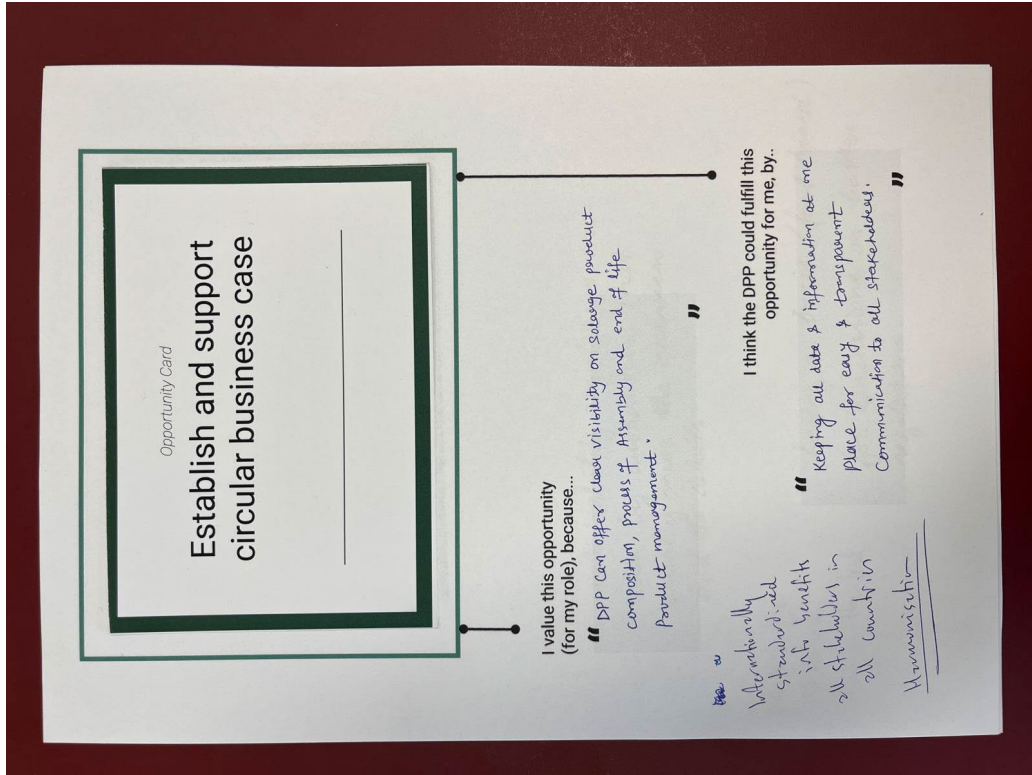


Figure X: Workshop A - Detailed opportunity 1

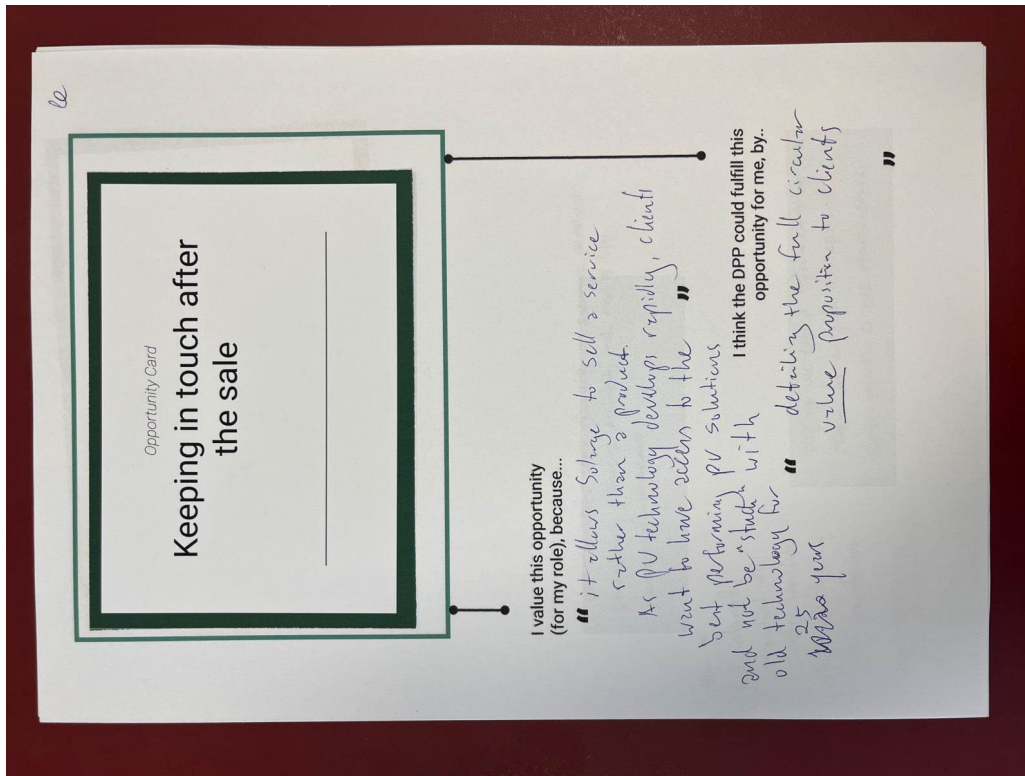


Figure X: Workshop A - Detailed opportunity 2

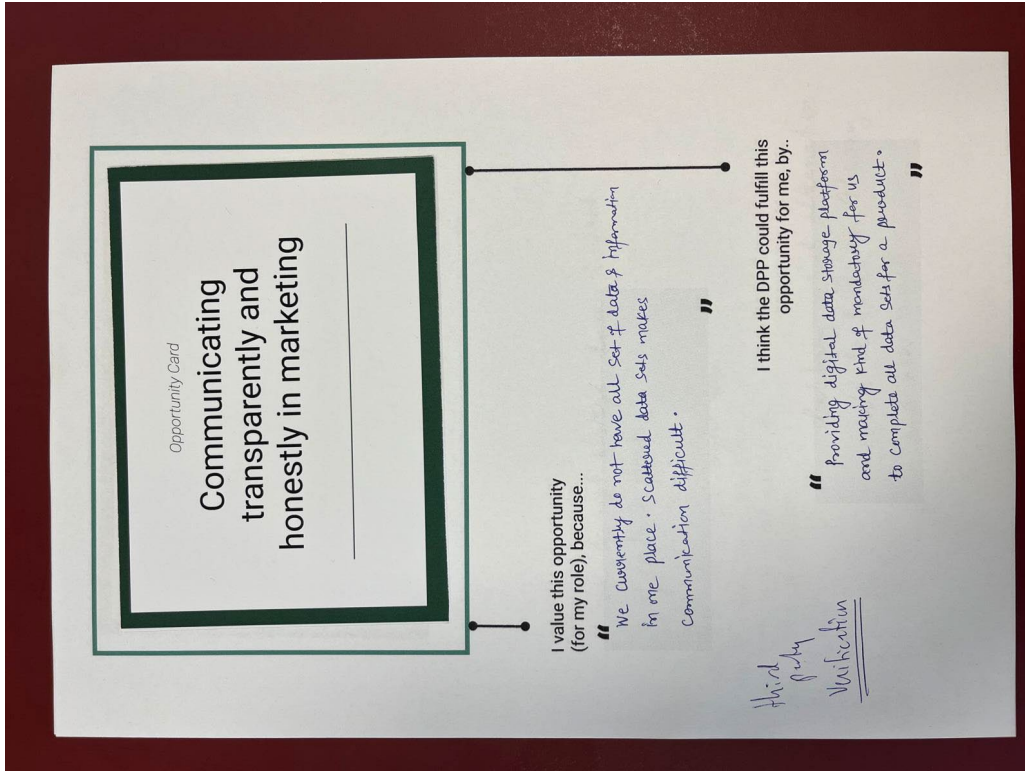


Figure X: Workshop A - Detailed opportunity 3

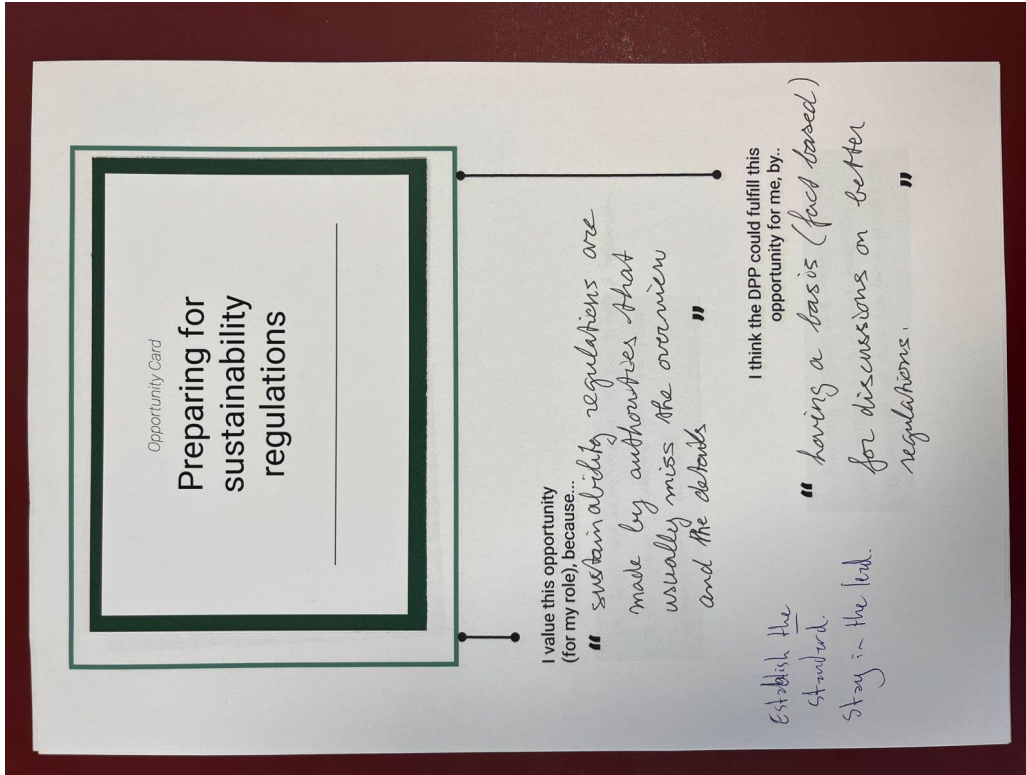


Figure X: Workshop A - Detailed opportunity 4

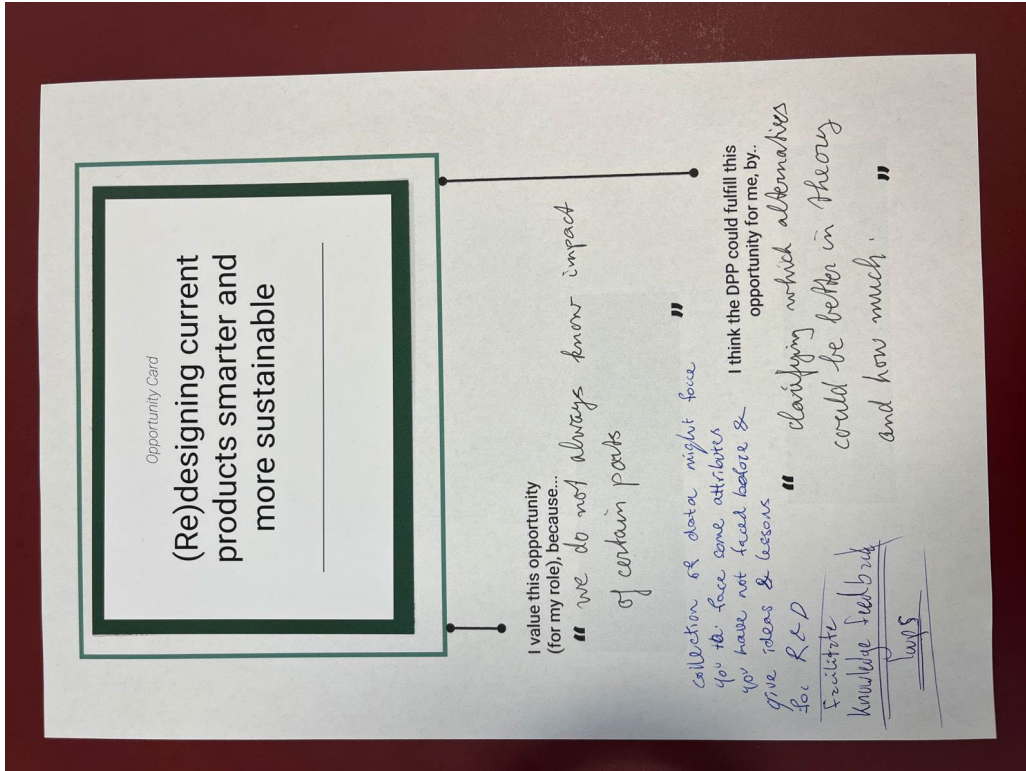


Figure X: Workshop A - Detailed opportunity 5

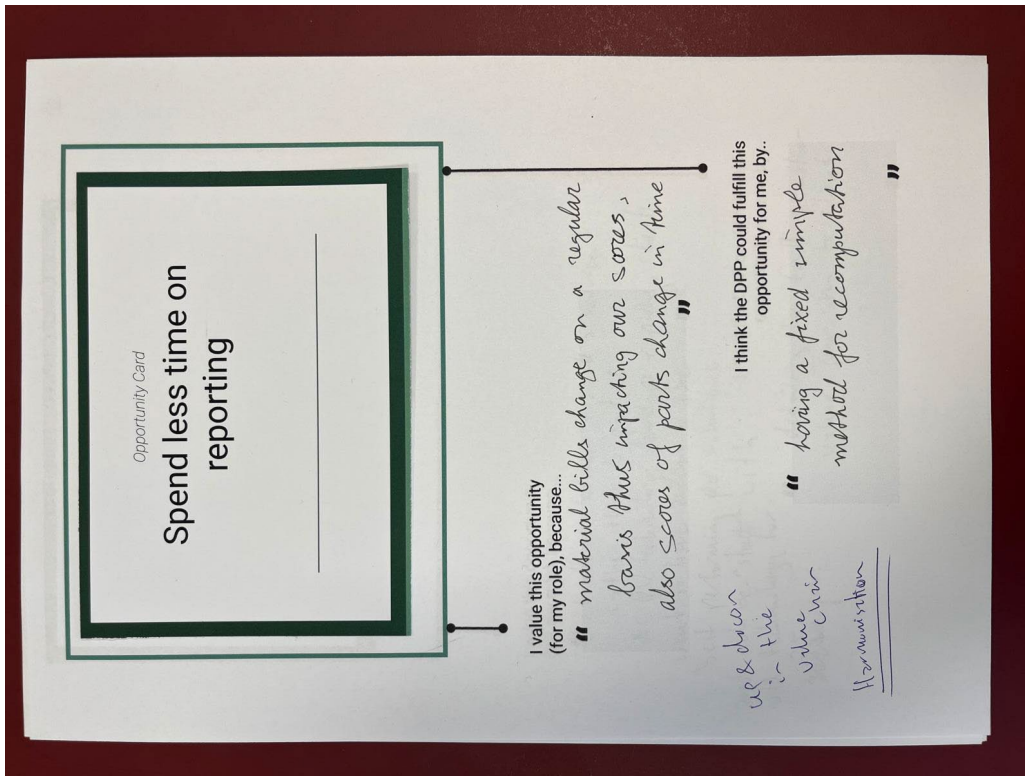


Figure X: Workshop A - Detailed opportunity 6

Workshop session B: Pre-fab concrete product manufacturer

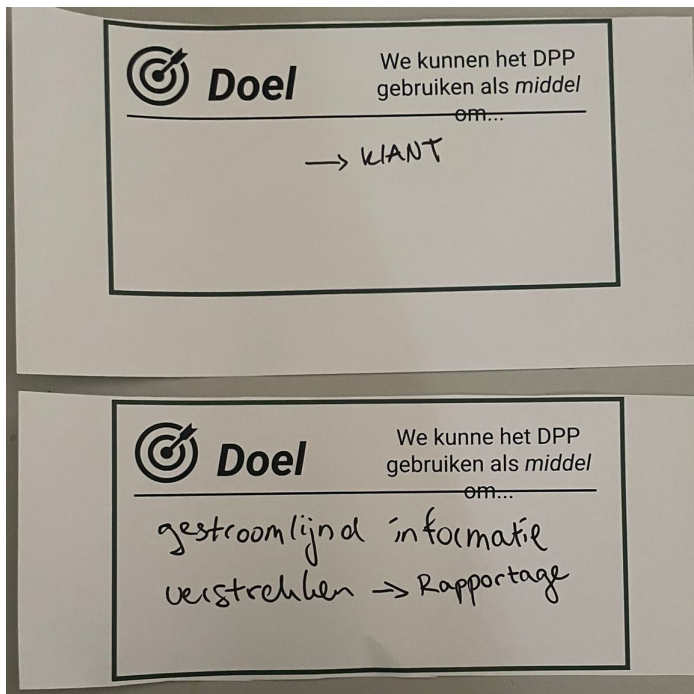


Figure x: Goals for DPP implementation

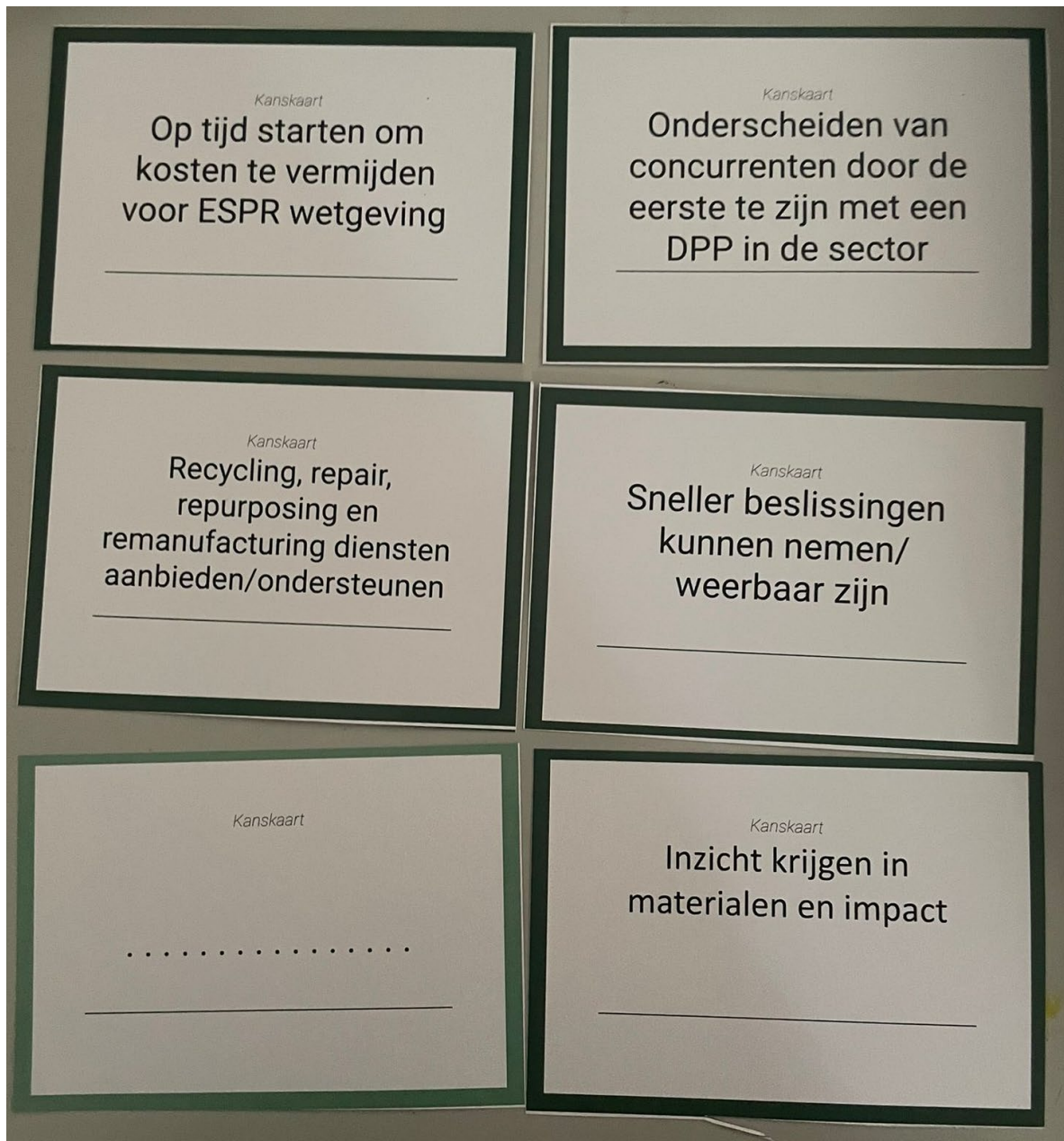


Figure x: Selected opportunities for DPP implementation

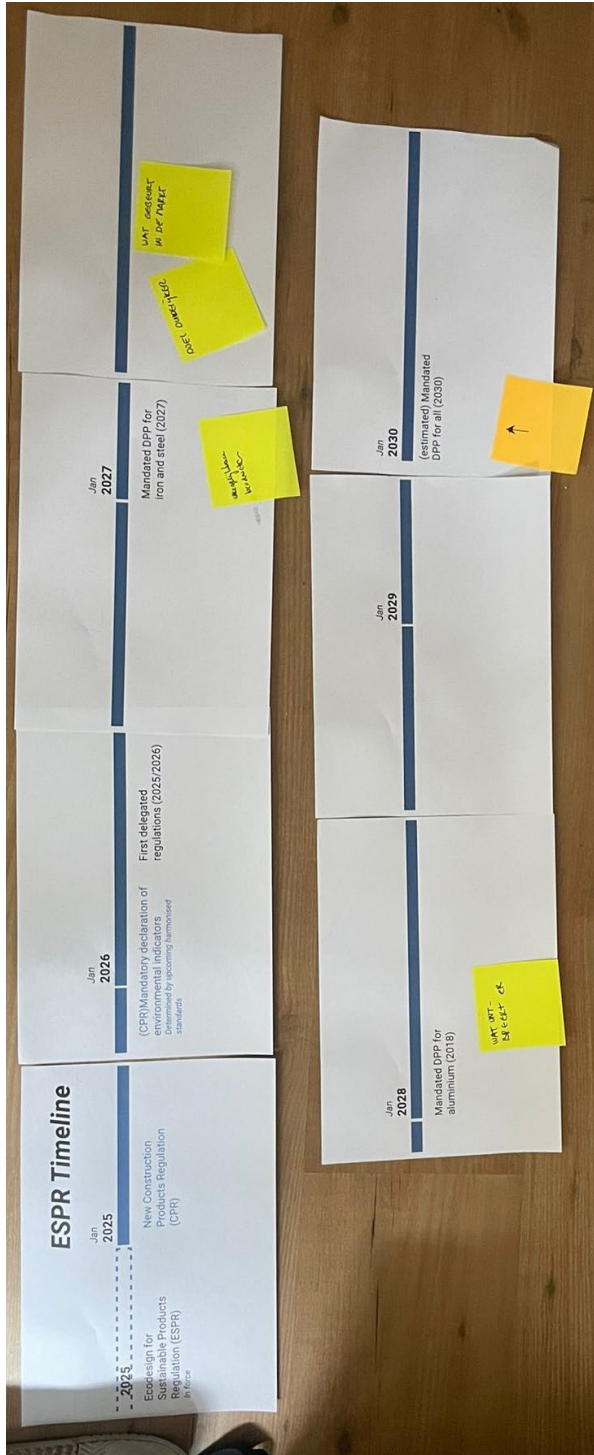


Figure X: implementation timeline

Workshop session B: Household interior consumer products manufacturer

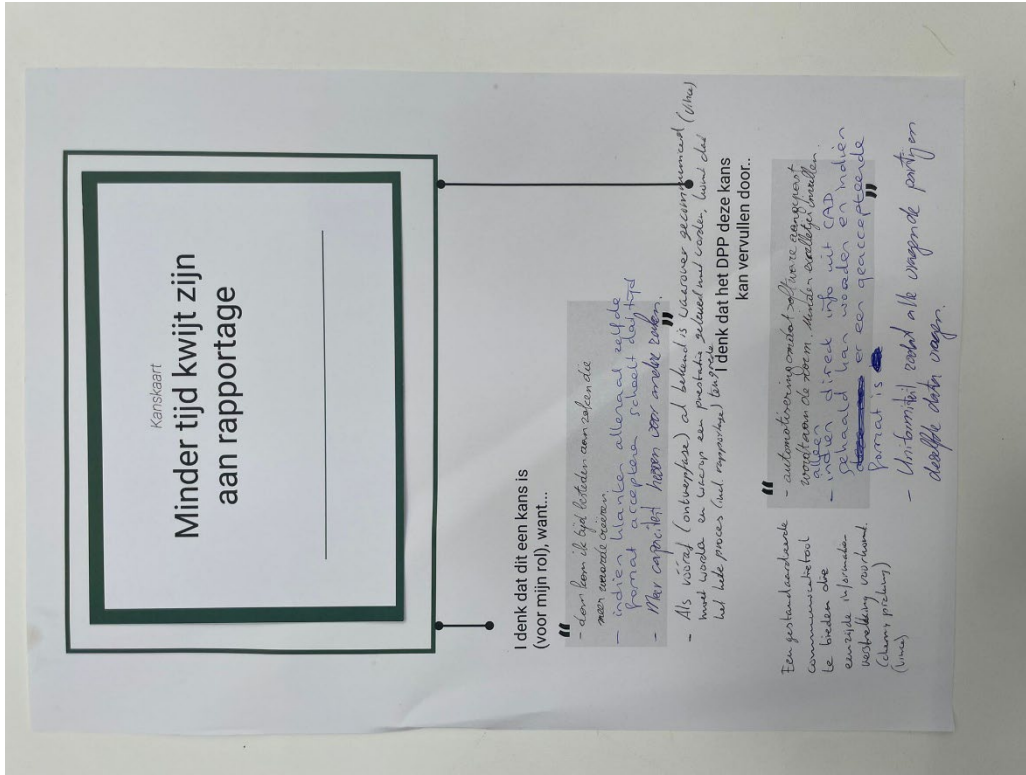


Figure X: Workshop C - Detailed opportunity 1

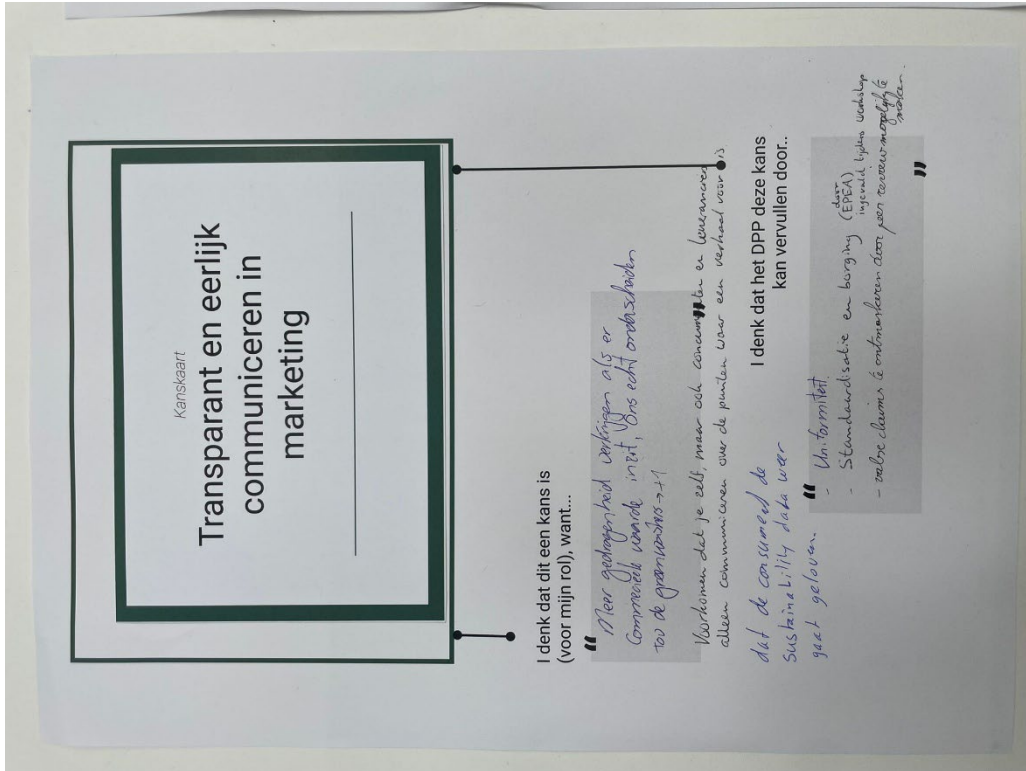


Figure X: Workshop C - Detailed opportunity 2

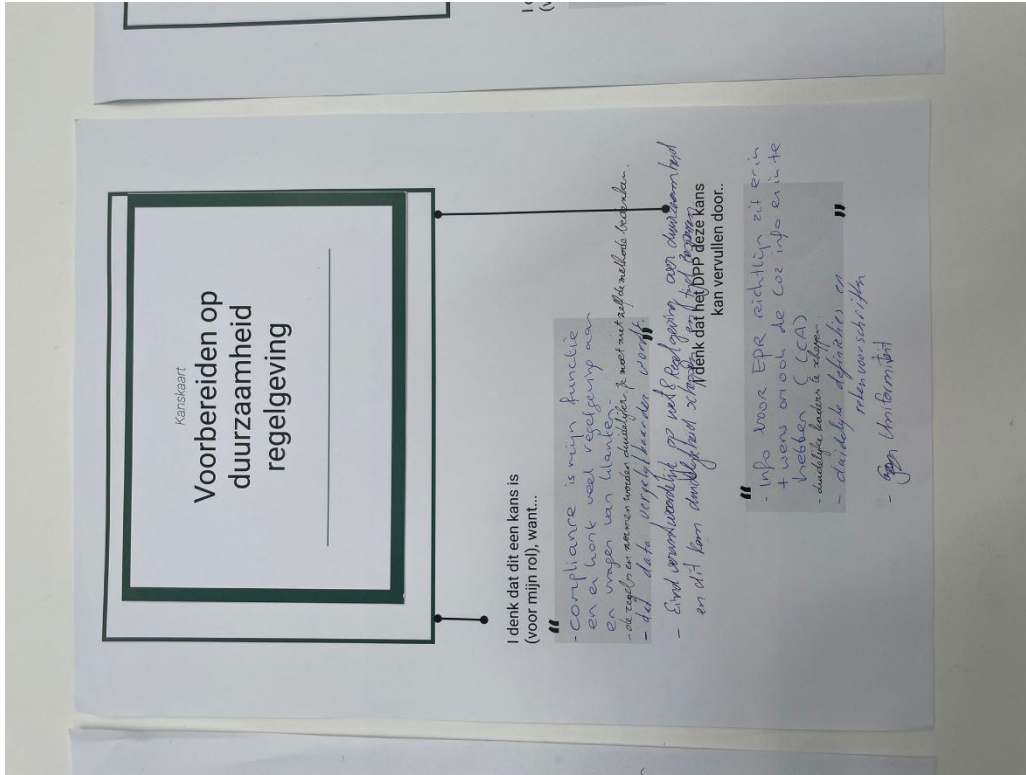


Figure X: Workshop C - Detailed opportunity 3



Figure X: Workshop C - Detailed opportunity 4

Appendix I: Opportunity cards