PRACTICE OF SUSTAINABLE DESIGN

Enabling reusable packaging

Image: Blueland


Image: Polina Tankilevitch - Pexels

Image: Elate Beauty

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PART 1

Discover & Define

KEY QUESTION

How can we enable businesses, especially small and midsize businesses (SMBs), to adopt reusable packaging at scale?

SUSTAINABILITY CHALLENGE

We face a plastics* crisis brought on by our dependence on single-use packaging. We need a system-wide shift in the way we approach packaging, including a move toward reusable packaging.

KEY QUESTION

How can we enable businesses, especially small and midsize businesses (SMBs), to adopt reusable packaging at scale?

*Petroleum-based plastics create the largest impacts throughout their lifecycle, from the extraction of oil through to end of life. But, plant-based plastics also create significant impacts and do not biodegrade in all environments. Therefore, the term "plastics" will be used throughout this document as an umbrella term referring to both petroleum- and plant-based polymers.

23%
of landfilled material in the U.S. is packaging[1]

40%
of plastic production is used for packaging[2]

5%
2030 global market for reusable packaging on current trajectory[3]

Packaging is responsible for significant resource use, greenhouse gas emissions, & environmental contamination.[4]

ONLY 9%
of all plastic ever produced has been recycled[5]

19 million
tons of plastic waste are leaked into the environment each year. 3% of that plastic reaches aquatic ecosystems.[6]

4x
The plastics industry creates 4x more greenhouse gas emissions than the airline industry.[7]

CHALLENGES TO WIDE-SCALE ADOPTION OF REUSABLE PACKAGING:

- **slow adoption by business**
  niche trials, limited collaboration[8]
- **low return rates**
  lack of convenient options for return/refill[9]
- **food safety & shelf life**
  concerns about spoilage & contamination[10]
- **lack of policy & economic incentives**
  no support for initial investment[11]
- **lack of standard reuse models & infrastructure**
  lack of efficiency, complex supply chains[12]

Framing the Problem: Key Issues

Environmental

Single-use packaging contributes to **climate change, resource depletion, habitat loss, and harm to wildlife**. For example:

- The percent of global oil production used for plastic could rise from 8% in 2012 to 20% by 2050.[13]
- Packaging accounts for 23% of landfilled material in the U.S. Landfills contribute to habitat loss, soil and water contamination, and climate change.[14]
- Billions of pounds of plastic can be found in the ocean, where it harms wildlife through consumption and entrapment.[15]

Economic

Adopting reusable packaging at scale will require **broad systems change and significant investment** from businesses.

- Recently passed extended producer responsibility (EPR) laws, which require businesses to take financial responsibility for their packaging waste, will shift economic incentives.[16]
- Transitioning to reusable packaging requires investment in design and infrastructure (e.g. cleaning facilities). We currently lack wide-scale, shared infrastricture for reuse.

Social

Plastics harm human health at every phase of their lifecycle, from the extraction of oil and gas through disposal. For example:

- Fracking contaminates air and water, leading to increased rates of asthma, birth defects, low birth weights, and childhood leukemia in nearby communities.[17]
- Microplastics can be found in air, soil, water, and the human body. Studies show that microplastics can cause an array of health impacts, including DNA damage, immune and endocrine disruption, and reproductive and developmental toxicity.[18]

Behavioral

Transitioning from single-use to reuse-based packaging systems will require **behavior change** on the part of businesses and consumers.

- Design for sustainable behavior (DfSB) strategies should be used to help facilitate the adoption of new habits and behaviors supporting reusable packaging.

Framing the Problem: Stakeholders

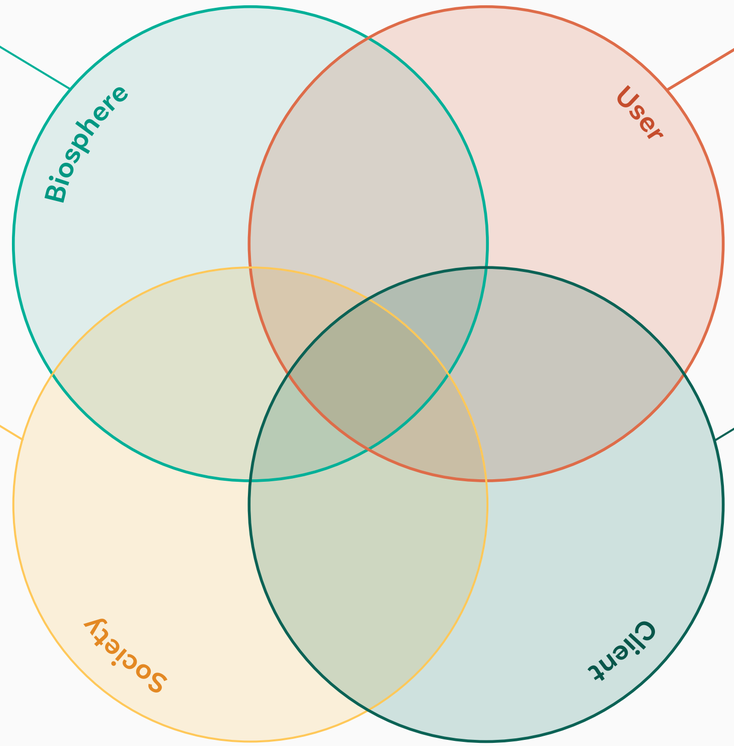
Stakeholders were identified using the approach for defining stakeholder needs outlined in *Okala Practitioner: Integrating Ecological Design.*

BIOSPHERE

— The air, soil, water and living organisms in our biosphere

SOCIETY

— Packaging designers & manufacturers
— Customers
— Communities impacted by business practices of SMBs at any scale



USER

— Owners of small to midsize businesses (SMBs)

CLIENT

— Organization supporting development of tool/initiative/ resource to enable reusable packaging

Framing the Problem: Unmet Needs & Opportunities

Unmet Needs

- Comprehensive and approachable resource(s) aimed at helping SMBs initiate and navigate a transition to reusable packaging
- Wide selection of desirable products available in reusable packaging (for customers)

Opportunities

- SMBs can be nimble, change-driving agents in their industries.[19]
- New/upcoming extended producer responsibility laws will shift the regulatory landscape around packaging, requiring businesses to keep pace.[20]
- Owners of SMBs are often short on time and funds. Support can enable them to make their businesses more sustainable.[21]

WHY SMALL TO MIDSIZE BUSINESSES*?

SMBs can be more agile and innovative

SMBs are better able to embrace sustainable practices than large corporations, either by adapting new approaches or integrating innovative approaches at the start-up stage.[22]

SMBs need support for sustainability

Sustainable practices are essential for SMBs to remain competitive, gain funding, and comply with regulations. SMBs will also need support to adapt to new and upcoming extended producer responsibility (EPR) legislation, as they lack the resources of larger corporations.[23]

SMBS are small but mighty

SMBs generate 43.5% of U.S. GDP and employ 46.4% of private-sector employees in the U.S.[24] Enabling SMBs to integrate reusable packaging could have wide-scale impact.

**Defined as businesses with fewer than 500 employees*[25]

Observe

Conversations with owners of small businesses that offer reusable and sustainable packaging revealed several themes.

Companies/organizations interviewed

- Elate Beauty
- Esembly
- GreenStar Food Coop
- Remembrance Farm
- Zero Waste Ithaca

Led by values

Businesses that currently offer reusable packaging do so because it aligns with their values and because the owners and employees are passionate about it.

Product first

Products in reusable packaging will only succeed if customers love the product, first and foremost. The packaging is a value add, and it can't detract from the experience of using the product.

"This is not a money-maker"

Multiple interviewees said that reusable packaging costs more money compared to single-use packaging. One company saw a drop in sales after introducing reusable packaging due to a slight price increase—even with an established base of sustainability-minded customers. Another interviewee acknowledged the up-front cost of purchasing containers and cleaning equipment.

Know your audience

Customers do like reusable packaging, and businesses can build a loyal following if their values, products, and packaging all align and resonate with their audience.

Sustainability is a journey, with hard work along the way

Founders put in a lot of blood, sweat, and tears to get their packaging to where it is now. They had to do "so much" of their own research and push vendors to try new things, plus adapt and evolve once they saw how packaging performed.

Find support

Business owners find support through partnerships with key vendors willing to work with them to test new ideas, and by sharing knowledge with other like-minded businesses. One business noted that seeking B Corp certification helped guide and strengthen their sustainability efforts.

Analyze

Several groups have published resources to help businesses understand and adopt reusable packaging.

This SWOT analysis asks: What works well about these existing resources? What can be improved?

Resources considered*

- Web content and online guides from the Ellen MacArthur Foundation
- Online publications from the UN Environment Programme
- Draft standards from PR3
- Web content from GoUnpackaged, a reusable packaging consultancy

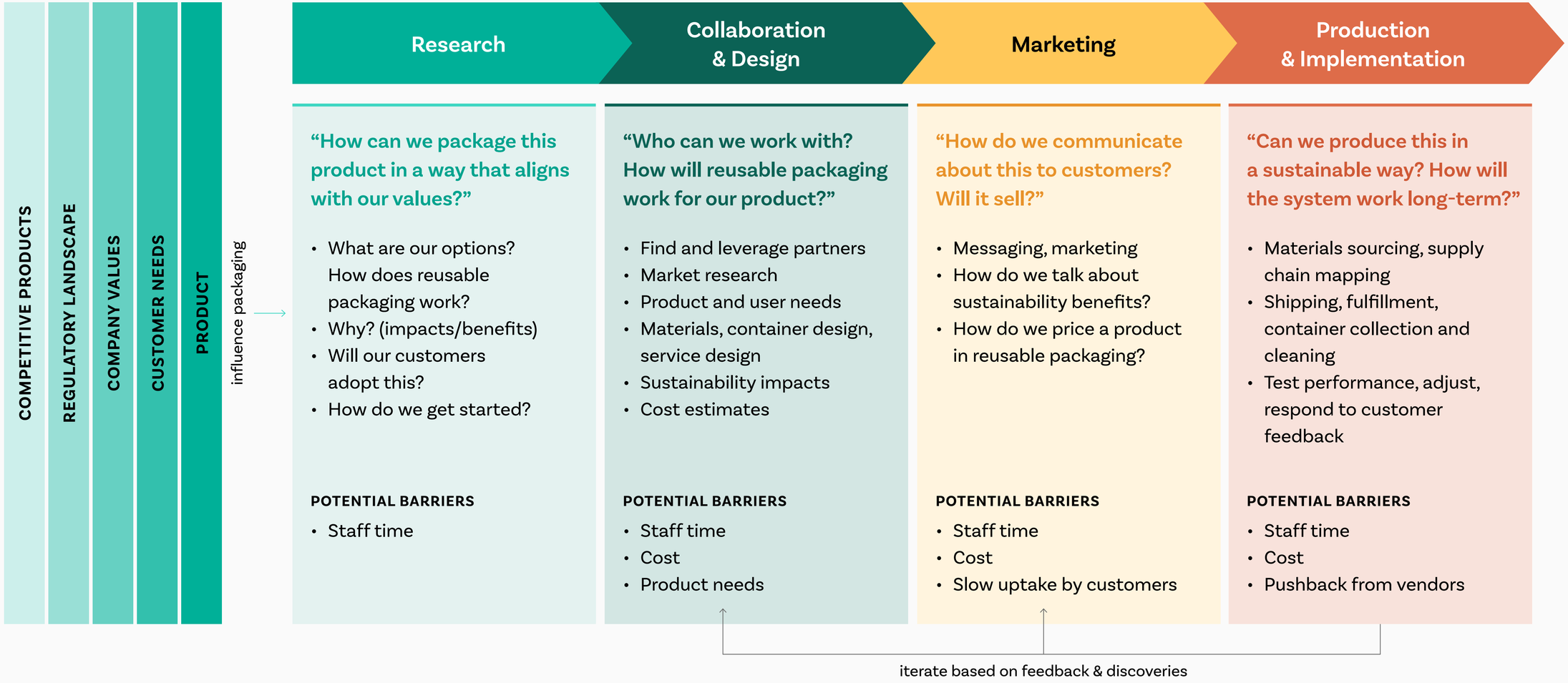
*These are a snapshot of what an average online search might reveal, not a complete representation of available information.

SWOT Analysis: Existing Reusable Packaging Resources for Businesses

STRENGTHS	WEAKNESSES
– Wealth of in-depth and expert information – Resources make a clear and compelling case for why reuse matters (impacts/benefits) – Compelling case studies show reuse in action – Positive vision for a circular future	– Scattered, must look in multiple places for all relevant info – Lack of clear next steps – Amount and presentation of information feels overwhelming – Many resources written for a more informed/ expert audience – Businesses may hesitate to reach out to a consultant as a first step (cost commitment)
OPPORTUNITIES	**THREATS**
– Consolidate and summarize wealth of information and resources in a single place – Clearly outline next steps (one to three) that interested businesses should take – Build a network and/or directory of reuse experts and partners – Encourage knowledge sharing – Reduce siloed research time to drive efficiency in efforts to adopt reusable packaging	– Current landscape of resources requires individual, siloed research effort from every business interested in making a change. This slows potential adoption of solutions. – Businesses may adopt less-than-ideal solutions without a full understanding of possibilities, processes, and the system surrounding reusable packaging.

Synthesize

This process diagram explores the experience of a business owner transitioning a product to reusable packaging.



Defining the Problem

PROBLEM STATEMENT

Businesses must transition from single-use to reusable packaging, quickly and at scale.

But, small and midsize businesses lack an approachable, persuasive, and comprehensive resource to help them initiate this transition.

STAKEHOLDERS

- Business owners
- Customers
- Product and packaging designers, manufacturers
- Communities in which businesses operate and source materials
- Workers along the product and packaging supply chains
- Planet Earth and the biosphere

KEY ISSUES

- Both businesses and customers need to be convinced to adopt reusable packaging (behavior change) and lack familiarity with reusable packaging
- Reusable packaging must be cost-effective and well-adapted to product and user needs to succeed
- Businesses and customers are sensitive to cost/price
- Businesses without existing sustainability values may be unlikely to adopt reusable packaging
- SMBs are not equipped to comply with new and upcoming EPR laws
- SMBs must navigate the process of adopting reusable packaging on their own and are short on time and funds to do their own research and implementation.

KEY DESIGN DRIVERS

- Empathy and understanding of business owners' perspectives and needs
- Understanding of the dynamics surrounding reusable packaging (and packaging more generally) at a systems level
- Messaging that distills complex information and inspires action
- Material safety & sustainability
- Consumer and product needs

DESIGN OBJECTIVES & STRATEGIES

Create quality designs
- Human-centered, design for communication

Optimize distribution system & optimize what is distributed
- Reusable packaging systems
- Life cycle assessment
- Reduce weight & volume

Optimize performance
- Design for use & accessibility

Be cost-effective
- Align costs with market, amortize over lifecycle, eliminate waste

Design for sustainable behavior
- Incentivize/enable desired behavior

Cycle resources
- Design for reuse, takeback, recycling, etc.

PART 2

Ideate

Key Issues

The key issues at right, identified via discovery, were explored using divergent thinking strategies.

KEY ISSUE 1

SMBs must navigate the process of adopting reusable packaging on their own and are short on time and funds to do their own research and implementation.

HOW MIGHT WE...

- help an SMB owner easily understand the process of adopting/implementing reusable packaging?
- reduce the time and financial burden of adopting reusable packaging?

KEY ISSUE 2

Both businesses and customers need to be convinced to adopt reusable packaging (behavior change) and lack familiarity with reusable packaging.

HOW MIGHT WE...

- inspire SMB owners to adopt reusable packaging?
- help SMB owners understand the reusable packaging landscape?
- help SMB owners understand the impacts of their current packaging?

Divergent Thinking Strategy: List-Making

How might we help an SMB owner easily understand the process of adopting/implementing reusable packaging?

- EPR packaging law info, SPC EPR tracker
- Any other relevant legislation, like requirements for food packaging, etc. — what do they need to know about labeling, etc.
- Four models of reuse — visual
- Customer journey(s) using reusable packaging ✸
- Customer perspectives on reusable packaging — positive, pain points, etc.
- Links to most helpful external resources (like Ellen Macarthur Foundation) — dig deeper
- Design process step-by-step
- Case study or two describing how businesses made it happen
- How to price & market reusable packaging — encourage customer adoption
- How to do user research/testing to understand customer needs
- Network/directory of experts/people to work with on implementation
- Examples of what it will cost
- Journey map: business adopting reusable packaging ✸
- Map/diagram process/flows for all four reuse models ✸
- Interactive journey map with questions, challenges, resources, actions, solutions at each step along the way ✸
- Reusable packaging landscape: who's doing it, prevalence, proven use cases, etc.
- Decision tree or interactive experience — understand which model of reuse may best fit their product ✸
- Lightweight LCA calculator
- Example LCAs comparing single-use and reusable ✸
- Cost calculator for example reusable packaging vs. single-use — where might cost break even, etc.
- Key concept/term definitions — reuse cycles, LCAs, EPR, etc.
- Gradate the info — shallow to deep — don't overwhelm

✸ = selected for further exploration

Divergent Thinking Strategy: Mindmap

How might we help an SMB owner easily understand the process of adopting/implementing reusable packaging?

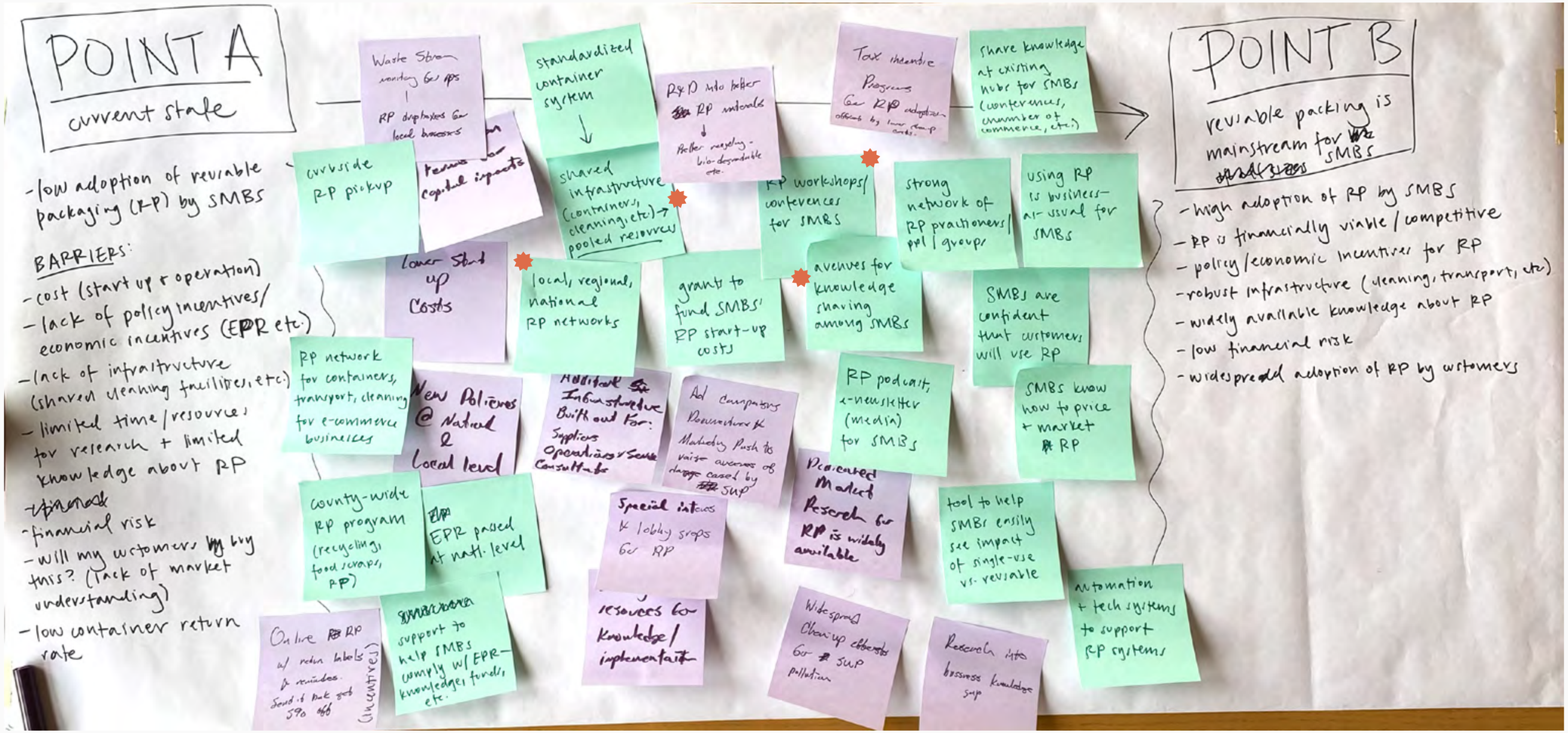
= selected for further exploration

Selected Ideas:

- visualize the implementation process (e.g. journey map)
- map/visualize the four reuse models *(return from home, return on the go, refill at home, refill on the go)*

Divergent Thinking Strategy: Gap Filling

From Point A (current state: low adoption) to Point B (future state: high adoption by SMBs)



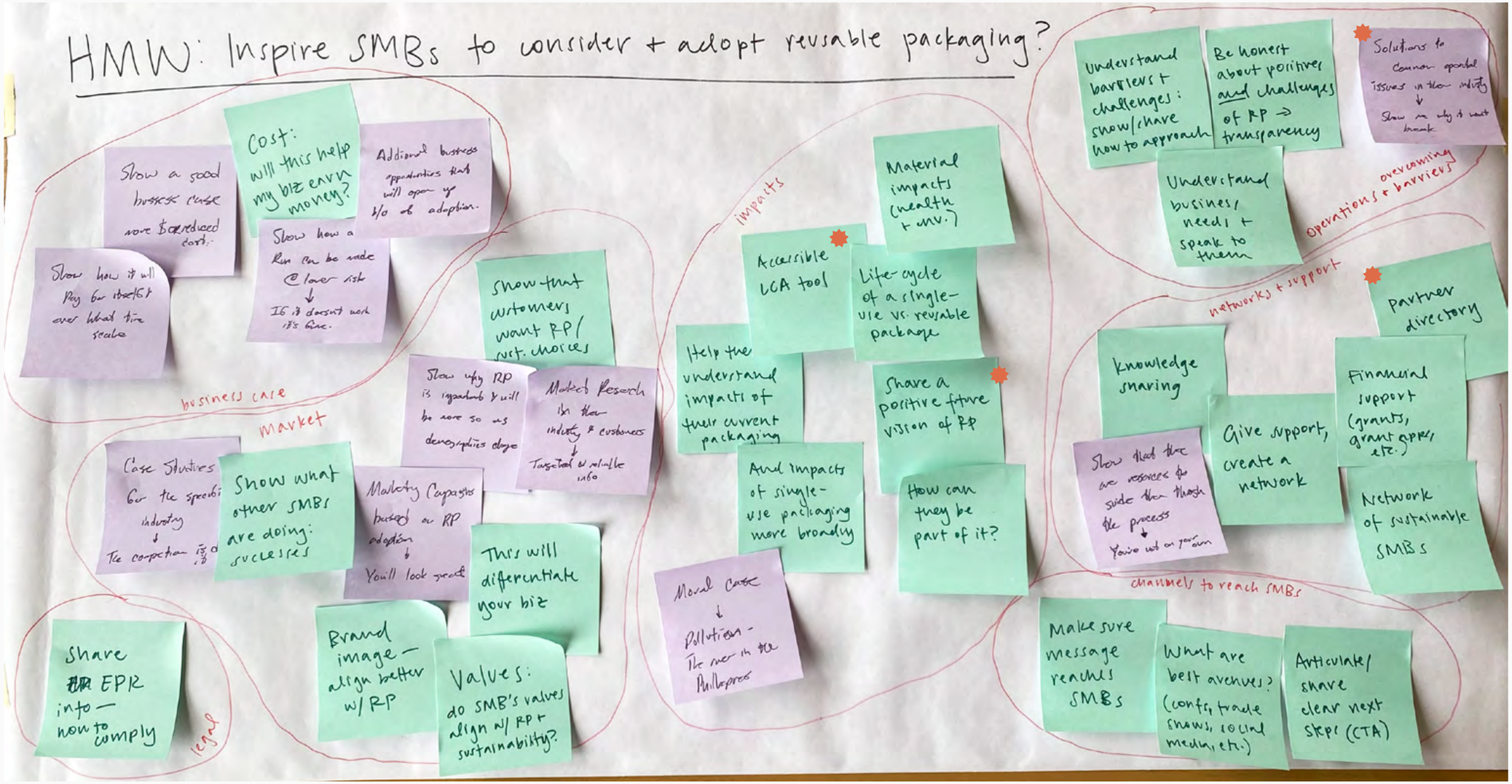
= selected for further exploration

Selected Ideas:

- fostering reusable packaging networks, shared infrastructure, and avenues for knowledge sharing among SMBs
- reusable packaging workshops for SMBs
- lobbying for policy change (e.g. adoption of EPR legislation)

Divergent Thinking Strategy: List Making + Clustering

How might we inspire SMB owners to adopt reusable packaging?



= selected for further exploration

Selected Ideas:

- accessible LCA tool to compare single-use vs. reusable
- craft & share positive future vision for reusable packaging
- build a directory of reusable packaging partners
- show why it won't work and ways to overcome common challenges

Ideas for Further Exploration

After synthesizing the results from brainstorming, these themes and ideas stood out.

Create Networks & Avenues for Knowledge Sharing

- Foster reusable packaging networks and avenues for knowledge sharing among SMBs
- Reusable packaging workshops for SMBs
- Foster development of shared infrastructure (cleaning, transport, etc.) for SMBs
- Build a directory of reusable packaging partners

Visualize the Process & Impacts

- Build an accessible LCA tool to compare the impacts of single-use and reusable packaging
- Visualize the implementation process (e.g. journey map), with challenges, resources, and actions mapped along the way
- Map/visualize the four reuse models
- Map customer journeys with reusable packaging
- Create a decision tree/interactive experience to help SMB owners visualize which model of reuse may best fit their product

Build Toward a Positive Future Vision

- Share a positive future vision for reusable packaging — and clear actions that SMB owners can take to contribute
- Build a movement of SMB owners lobbying for policy change to support reusable packaging

PART 3

Assess

Lifecycle Assessment: Single-Use vs. Reusable Bottles

To better understand the impacts of reusable packaging, a common packaging form—a bottle with hand pump—was selected for exploration using Sustainable Minds' LCA software. Four materials for a reusable bottle—HDPE, recycled polypropylene, aluminum, and PLA—were selected for comparison against a single-use HDPE bottle.

Image: Mrs. Meyers

COMPONENT A

Reusable 100% recycled polypropylene bottle with pump

Image: ecyo

COMPONENT B

Reusable 50% recycled polypropylene bottle with pump

Image: Myni

COMPONENT C

Reusable bioplastic (PLA) bottle with pump

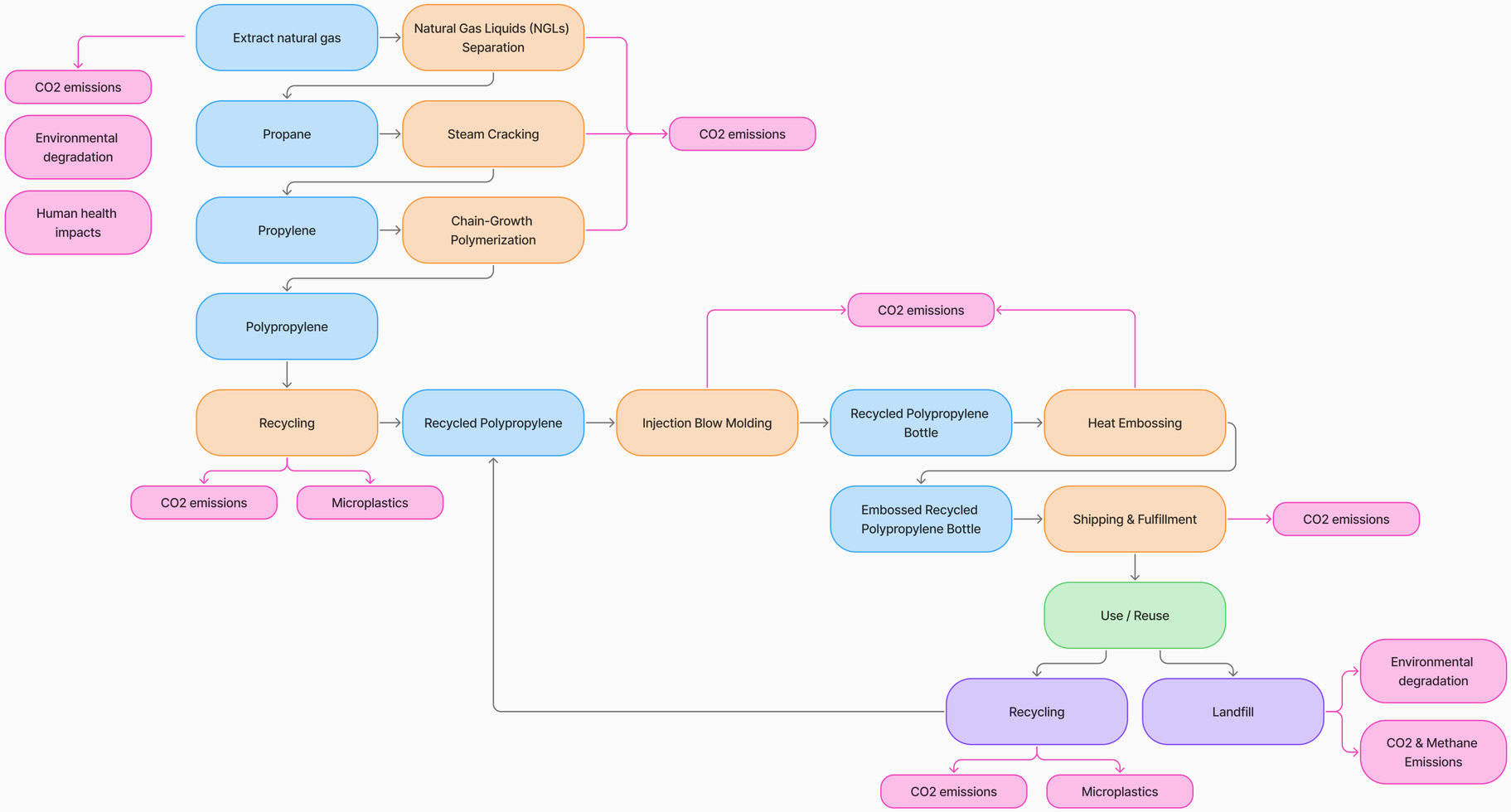
Image: Plaine Products

COMPONENT D

Reusable aluminum bottle with pump

Process Tree: Reusable Recycled Polypropylene Pump Bottle

This process tree maps the materials, processes, and impacts involved in creating a recycled polypropylene bottle.



Lifecycle Assessment Results

Reference Concept

Single-use HDPE bottle with pump

12 mPts/unit

Concepts for Comparison

LOWEST IMPACT

Reusable HDPE bottle with pump

1.5 mPts/unit **87%** performance improvement

Reusable 50% PCR PP bottle with pump

1.6 mPts/unit **86%** performance improvement

Reusable bioplastic (PLA) bottle with pump

3.1 mPts/unit **74%** performance improvement

Reusable aluminum bottle with pump

6.7 mPts/unit **42%** performance improvement

TAKEAWAYS

The LCA results clearly demonstrate that **reusable packaging can signifcantly reduce impacts** when compared to a single-use alternative.

While the reusable HDPE bottle had the highest performance improvement (87%), **all the reusable options are viable solutions, depending on product, package, and consumer needs.**

See appendix for full LCA results, including lifecycle inventories for each material.

PART 4

The Idea

THE IDEA:

Interactive LCA Visualizer

Helping SMB owners understand the impacts of single-use vs. reusable packaging using pre-loaded data

Project Goals

MAIN GOAL:

Present LCA data in an engaging and comprehensible way to persuade business owners to take an action step toward implementing reusable packaging

SUPPORTING GOALS:

- Help owners of SMBs understand the relative impacts of single-use and reusable packaging
- Introduce SMB owners to the concept of LCAs and to the impacts created by packaging
- Support SMB owners as they adapt to newly adopted extended producer responsibility (EPR) laws

TACTICS

- Present tool as **part of a larger resource** that **lays out options, impact, resources, and first steps** for SMBs interested in but unfamiliar with reusable packaging
- Share approachable data as a **“decision-support technique”** that **breaks down complex information** to help people reach more sustainable decisions.
- Invite users to take a **concrete action step** after using the tool to build **commitment and engagement**.

PART 5

Guiding Strategies

Sustainable Design Strategies

These three key sustainable design strategies guided the development of this project.

Human-Centered Design

- Understand user needs, behaviors, and experiences to create effective and user-friendly solutions
- Prioritize accessibility and user experience

Design for Sustainable Behavior

- Leverage design to support sustainable behavior, including behavior change
- Support decision-making by breaking down complex information
- Provide compelling, clear feedback
- Build motivation through empowering messaging

The Living Principles

- Four streams of sustainability—environment, people, economy, and culture—as a roadmap for sustainable design
- Assess and iterate throughout the design process

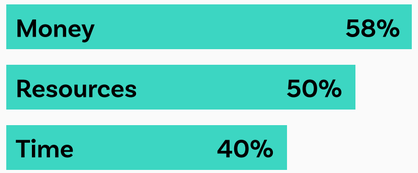
Understanding the Audience

The LCA visualizer will be created as part of a larger reusable packaging resource intended for owners of small to midsize businesses (SMBs).

PRIMARY AUDIENCE:
SMB owners with existing sustainability values

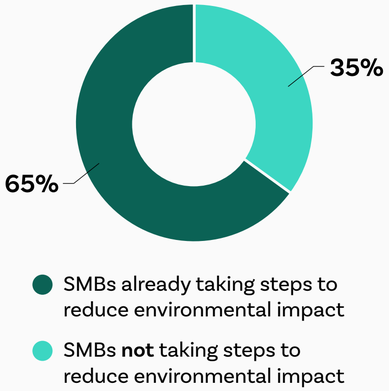
SECONDARY AUDIENCE:
SMB owners neutral about sustainability

What barriers stop SMBs from taking sustainability action?



Most common sustainability actions taken by SMBs

- Recycling
- Renewable materials
- Locally sourced materials
- Renewable energy
- Virtual meetings & remote work



61%
share of SMBs owned by men

22%
share of SMBs owned by women

14%
share of SMBs owned equally by men and women

62%
of SMBs have been in business at least 6 years

63%
of SMBs have fewer than 5 employees

WHY SMALL TO MIDSIZE BUSINESSES*?

SMBs can be more agile and innovative

SMBs are better able to embrace sustainable practices than large corporations, either by adapting new approaches or integrating innovative approaches at the start-up stage.[27]

SMBs need support for sustainability

Sustainable practices are essential for SMBs to remain competitive, gain funding, and comply with regulations. SMBs will also need support to adapt to new and upcoming extended producer responsibility (EPR) legislation, as they lack the resources of larger corporations.[28]

SMBS are small but mighty

SMBs generate 43.5% of U.S. GDP and employ 46.4% of private-sector employees in the U.S.[29] Enabling SMBs to integrate reusable packaging could have wide-scale impact.

**Defined as businesses with fewer than 500 employees[26]*

Statistics courtesy Quickbooks[30] and Pew Research Center[31]

User Persona

PRIMARY AUDIENCE

Business Owner: Enthusiastic about Sustainability

Name:
Sarah Thompson

Age:
42

Gender:
Female

Location:
Portland, Oregon

Education:
Bachelor's Degree in Business Administration

PERSONAL DEMOGRAPHICS

Household Income: $120K annually
Marital Status: Married, two children (ages 9 and 12)
Values: Transparency, community, environmental stewardship

BUSINESS PROFILE

Business Type: Mid-sized sustainable personal care and home goods store (brick-and-mortar + e-commerce)
Business Size: 25 employees, ~$3 million annual revenue
Sustainability: Established sustainability values, limited resources to build strategy or track initiatives

PAIN POINTS

- **Cost vs. Sustainability:** Struggles to balance sustainable sourcing with competitive pricing
- **Supply Chain Transparency:** Difficulty verifying vendors' green claims and certifications
- **Customer Education:** Unsure about best ways to communicate about sustainability to customers
- **Time Constraints:** Wears many hats (marketing, HR, operations) leaving little time for strategy

MOTIVATIONS & GOALS

- **Mission-Driven:** Wants to make sustainability the default choice for everyday consumers
- **Brand Loyalty:** Aims to build a loyal customer base who aligns with her personal & business values around sustainability
- **Innovation:** Interested in adopting sustainable/reusable packaging and carbon-neutral shipping
- **Growth:** Looking to scale the online store and possibly expand to new urban locations
- **B-Corp Certification:** Interested in becoming B-Corp certified but unsure about process and time commitment

TECHNOLOGY USE

Tools: Shopify, QuickBooks, Google Workspace, Canva, Mailchimp
Social Media: Instagram, Pinterest, Facebook
Learning Style: Prefers podcasts, how-to videos, and short webinars (low time commitment)

User Persona

SECONDARY AUDIENCE

Business Owner: Neutral about Sustainability

Name:
Ryan Mitchell

Age:
45

Gender:
Male

Location:
Denver, Colorado

Education:
Bachelor's Degree in Brewing Science

PERSONAL DEMOGRAPHICS

Household Income: $170K annually
Marital Status: Married, one child (age 5)
Values: Quality, local sourcing, community

BUSINESS PROFILE

Business Type: Local craft beer brewery, selling beer onsite and at retail locations
Business Size: 18 employees, ~$1.75 million annual revenue

PAIN POINTS

- **Cost of Ingredients:** High-quality, unique ingredients can be expensive, prices fluctuate
- **Margins:** Craft beer pricing is competitive, and higher-quality ingredients and small-batch production leave little room for profit
- **Labor Shortages:** Difficulty in finding skilled brewing staff
- **Brand Awareness:** Standing out in a local market filled with breweries and establishing a loyal customer base
- **Time Constraints:** Wears many hats (operations, brewing management, marketing) leaving little time for strategy

MOTIVATIONS & GOALS

- **Community Connection:** Ryan wants his brewery to be known for its commitment to local partnerships
- **Expansion:** Aims to grow distribution locally and potentially regionally while keeping the brewery's small-batch focus and customer-centric approach
- **Operational Efficiency:** Focused on improving production processes, reducing waste, and streamlining operations to increase profitability without sacrificing quality
- **Building Brand Loyalty:** Focused on creating beers that resonate with craft beer enthusiasts and casual drinkers
- **Sustainability (if cost-effective):** Interested in exploring more sustainable options, particularly in packaging and energy use, but only if they align with the brewery's bottom line and consumer interest

TECHNOLOGY USE

Tools: Square, QuickBooks, social media analytics tools
Social Media: Instagram and Facebook
Learning Style: Prefers hands-on learning, networking with other local brewers, and reading industry blogs or attending brewing conferences

Encouraging Behavior Change & Supporting Decision-Making

DEFINITION: Design for Sustainable Behavior (DfSB) is the practice of creating products, systems, or environments that **encourage or guide users toward behaviors that reduce environmental impact**. It leverages design to **make sustainable choices easier, more intuitive, or more rewarding**.

DESIGN FOR SUSTAINABLE BEHAVIOR APPROACHES:

Provide feedback

Provide timely feedback to show the impact of a user's behavior.

Build understanding

Explain why a behavior is more sustainable to foster intrinsic motivation.

Make impacts visible

Make the value of actions visible, understandable, and accessible.

Break down complex info

Break down complex information to help users reach more sustainable decisions. Make interactions clear, simple, and easy to complete.

Use the power of social proof

Encourage users to make a public commitment. Show users that others are taking similar actions.

Accentuate the positive

Share the costs of unsustainable behavior, but focus on positive messages that create a sense of agency and encourage action.

Inform *and* persuade

Factual information alone is not enough to change behavior. Balance information with approaches that appeal to emotions and social norms.

"Facts and raw data can be persuasive, but only if they are contextualized and presented in appealing, comprehensible ways."

—Marilyn DeLaure, "Discourse Design," *Routledge Handbook of Sustainable Design*

"For a target behavior to happen, a person must have sufficient motivation, sufficient ability, and an effective trigger."

—BJ Fogg, quoted in *Okala Practitioner: Integrating Ecological Design*

The Living Principles: Four Streams of Sustainability

The Living Principles, created by AIGA, is an actionable framework created to help designers integrate sustainability into their work. It distills sustainability into four streams: environment, people, economy, and culture. The final result of this project will be assessed using The Living Principles scorecard.

Environment

- Promote adoption of reusable packaging by businesses; enable transition away from single-use packaging
- Design the tool following principles for sustainable web design[32]
- Digital rather than physical: fewer material impacts, but reliant on energy for servers and inputs for users' devices

People

- Meet a genuine need for small business owners (accessible reusable packaging info)
- Build networks and encourage knowledge-sharing (ultimately, via broader resource)

Economy

- Support sustainability-oriented small to midsize businesses
- Support local and regional economies
- Communicate economic and sustainability value of reusable packaging

Culture

- Promote adoption of reusable packaging by businesses
- Support behavior change and sustainable decision-making
- Promote sustainability as a core business concept/value
- Build networks and encourage knowledge-sharing (ultimately, via broader resource)

PART 6

Developing the Tool

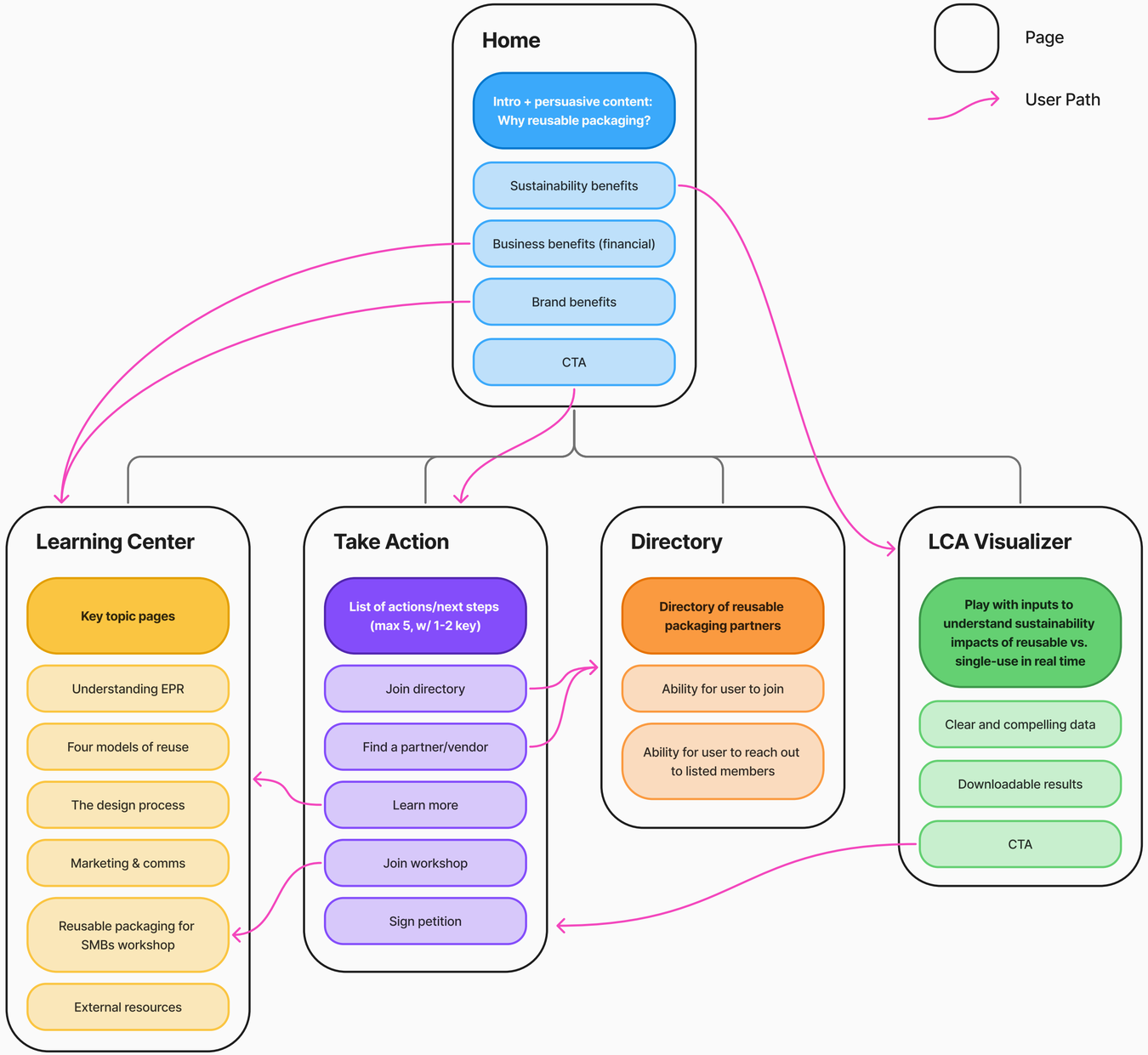
This section details the process of developing the LCA visualizer, including sketching, prototyping, and documenting how the tool will nest within a broader reusable packaging resource.

MAIN GOAL FOR THE TOOL:

Present LCA data in an engaging and comprehensible way to persuade business owners to take an action step toward implementing reusable packaging

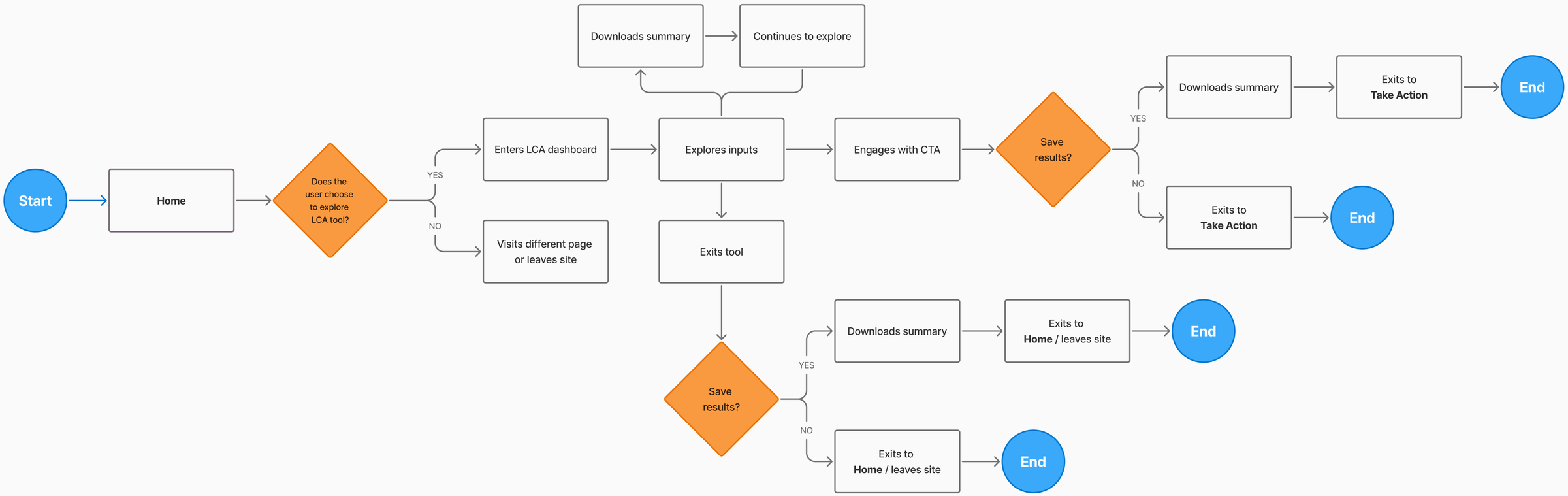
Site Map

The site map outlines how the LCA visualizer nests within a website that presents options, impact, resources, and first steps for SMB owners interested in reusable packaging.



User Flow: Using the LCA Visualizer

The user flow maps users' steps, decisions, and interactions while using the LCA visualizer.



Sketching:
LCA Visualizer Interface

Early sketches of the user interface explored several key questions:

How does the user view LCA results?

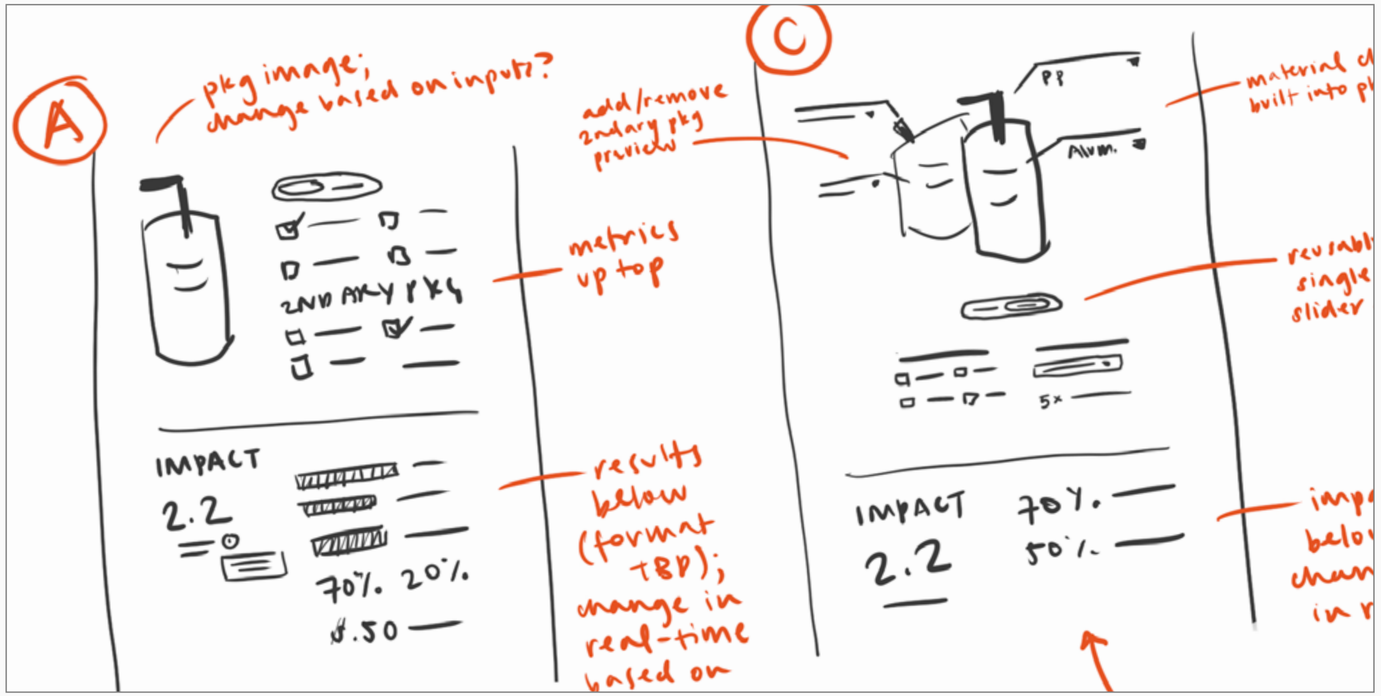
- If the results appear on the same screen, are they shown beside the package, or below?
- Does the user need to scroll to view the results?

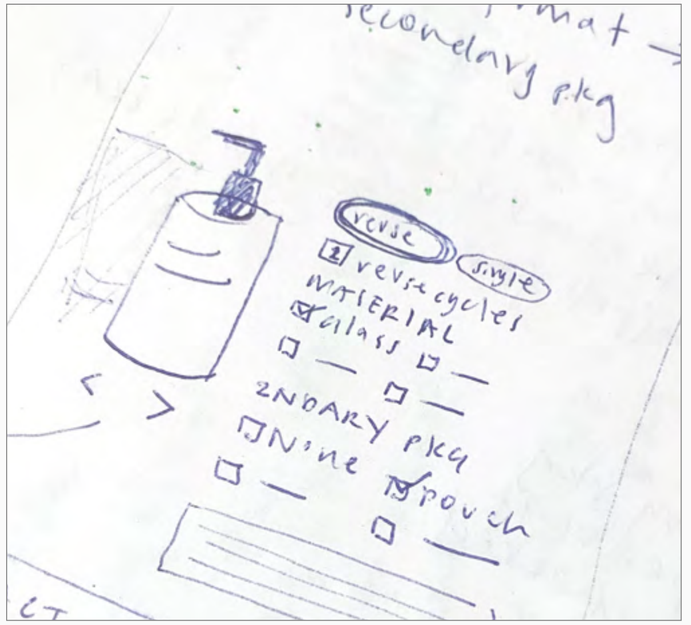
Where does the user enter inputs?

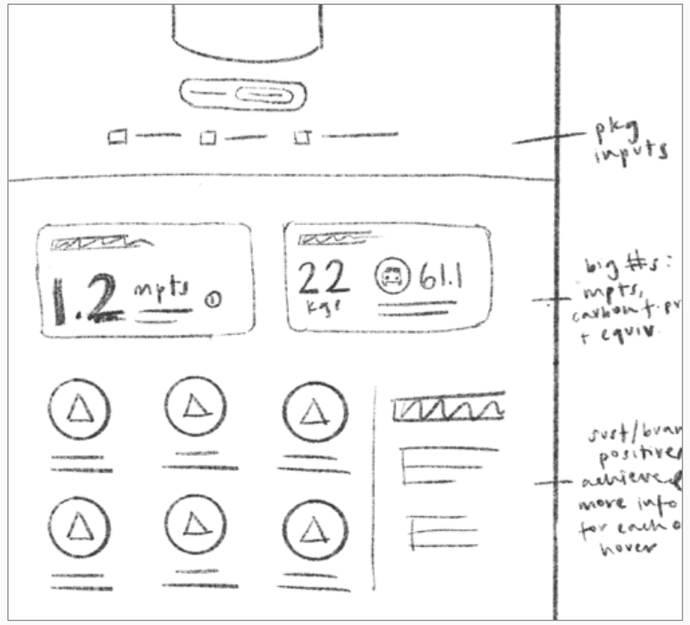
- Does it feel more intuitive to combine input selections with the package preview?
- How does this change the experience of viewing results?

Do results change in real-time?

- Do results appear on the same screen, or a separate screen?
- Do results change as inputs change, or do users click to update?



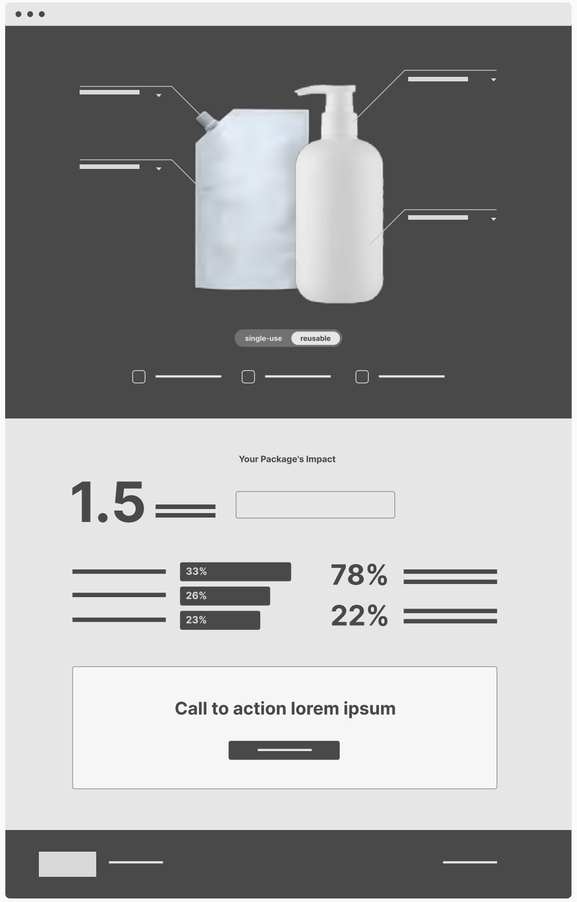




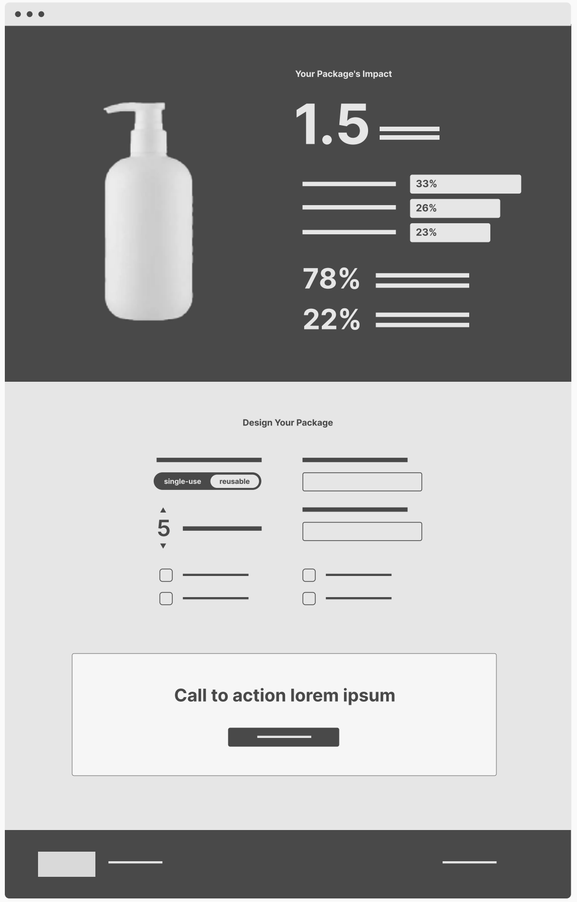
Wireframing

Wireframing allowed further development of the interface, exploring three main directions.

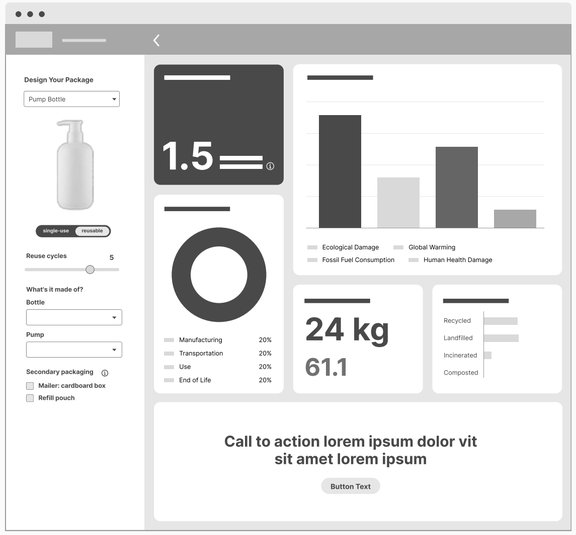
A Inputs Above the Fold; Impacts Below



B Impacts Above the Fold; Inputs Below



C Dashboard with Side-by-Side View of Inputs & Impacts



Selected for further development

The side-by-side view allows users to easily see the impacts of their inputs.

User Interface Design

KEY FEATURES:

Side-by-Side View

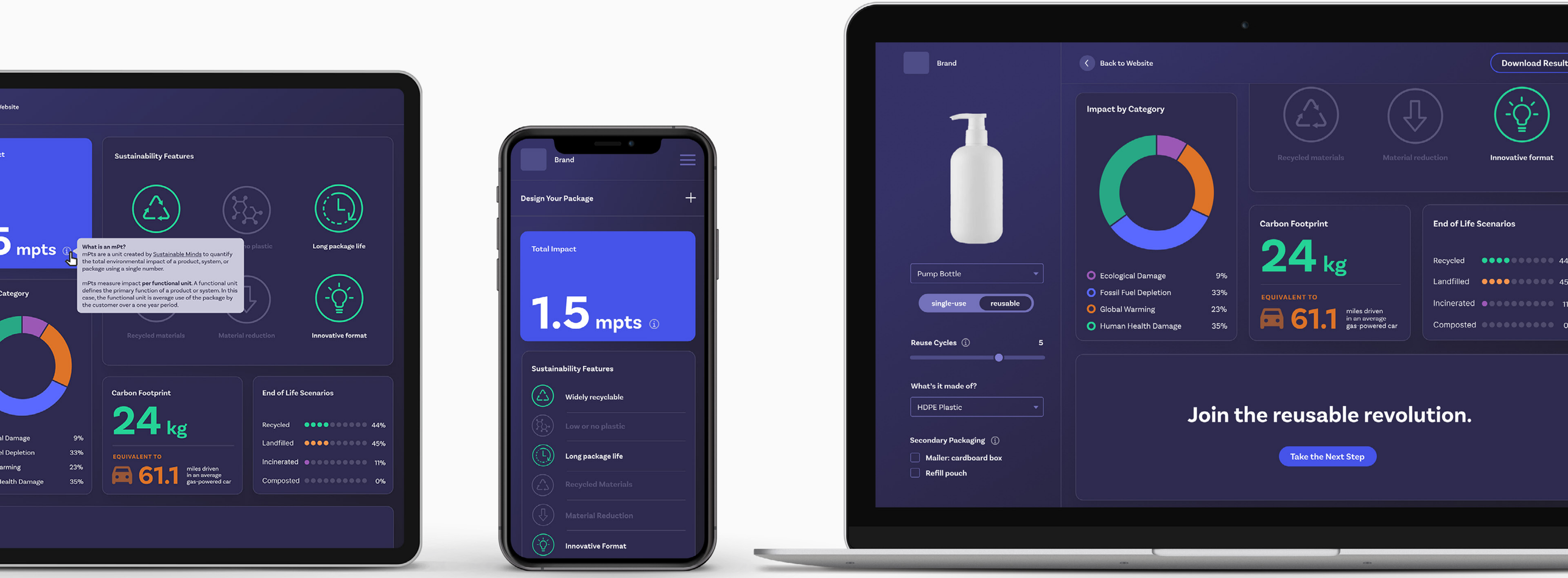
Dashboard format allows users to easily see the impacts of their inputs.

Clear, Streamlined Data

Designed to be clear and visually engaging, with a focused amount of content. The design follows best practices for user experience: streamlined data, supporting visuals, and minimal scrolling.[33]

Real-time Feedback

The dashboard provides clear and immediately visible feedback based on user choices.


Sustainability Features
Long package life
Recycled materials
Material reduction
Innovative format
What is an mPt?
mPts are a unit created by Sustainable Minds to quantify the total environmental impact of a product, system, or package using a single number.
mPts measure impact per functional unit. A functional unit defines the primary function of a product or system. In this case, the functional unit is average use of the package by the customer over a one year period.
Carbon Footprint
24 kg
EQUIVALENT TO
61.1
miles driven in an average gas-powered car
End of Life Scenarios
Recycled 44%
Landfilled 45%
Incinerated 11%
Composted 0%
Brand
Design Your Package
Total Impact
1.5 mpts
Sustainability Features
Widely recyclable
Low or no plastic
Long package life
Recycled Materials
Material Reduction
Innovative Format
Brand
Back to Website
Download Result
Impact by Category
Ecological Damage 9%
Fossil Fuel Depletion 33%
Global Warming 23%
Human Health Damage 35%
Recycled materials
Material reduction
Innovative format
Carbon Footprint
24 kg
EQUIVALENT TO
61.1
miles driven in an average gas-powered car
End of Life Scenarios
Recycled
Landfilled
Incinerated
Composted
Pump Bottle
single-use
reusable
Reuse Cycles 5
What's it made of?
HDPE Plastic
Secondary Packaging
Mailer: cardboard box
Refill pouch
Join the reusable revolution.
Take the Next Step

6: DESIGN DEVELOPMENT

Total Impact

mPts score, generated by Sustainable Minds, provides an immediate snapshot of the package's overall performance.

Package Inputs

Users can select:
- Package format
- Single-use or reusable
- Number of reuse cycles
- Material
- Secondary packaging

Sustainability Features

Key features provide a quick read of the package's overall sustainability performance.

Empowering CTA

Final moment in the experience is a call to action that invites the user to join others in adopting reusable packaging.

Sustainability metrics generated by Sustainable Minds, EcoImpact COMPASS, and EPA Greenhouse Gas Equivalencies Calculator

6: DESIGN DEVELOPMENT

Tooltips Add Context

Tooltips appear on hover to provide deeper information for key concepts, including the mPts scoring system.

Downloadable Results

Users can download a report to save results for future reference and comparison.

Detailed Data

Dashboard provides a focused set of metrics, with key data up top and more detailed data presented on smaller cards.

Sustainability metrics generated by Sustainable Minds, EcoImpact COMPASS, and EPA Greenhouse Gas Equivalencies Calculator

Comparing Results: Reusable Package

Results for a **reusable pump bottle** made from HDPE (petroleum-based plastic).

These results do not include secondary refill packaging, which assumes that the system works in one of two ways:

- **Refill on the go:** Users refill their containers away from home, e.g. from a bulk dispenser in-store
- **Return on the go:** Users return their containers away from home, e.g. in a bin in-store

These options are based on the Four Models of Reuse outlined by the Ellen MacArthur Foundation.[34]

Sustainability metrics generated by Sustainable Minds, EcoImpact COMPASS, and EPA Greenhouse Gas Equivalencies Calculator

Comparing Results: Single-Use Package

Results for a **single-use pump bottle** made from HDPE (petroleum-based plastic).

These results assume standard use of a single-use bottle, with an average use time of six months by the customer before disposal.

For future development:
Future iterations of this tool will explore adding functionality that allows users to compare multiple results side by side.

Sustainability metrics generated by Sustainable Minds, EcoImpact COMPASS, and EPA Greenhouse Gas Equivalencies Calculator

Conclusion

Assessing Sustainability with The Living Principles

The final result of this project was scored according to AIGA's Living Principles scorecard.

The score provides a snapshot of the tool's sustainability strengths, along with areas for improvement or continued focus during development.

For example, to improve the tool's People score, human health impacts of various materials could be taken into account in more depth in the dashboard metrics.

Or, as the tool and encompassing resource are developed, continued user research should focus on including the viewpoints of a diverse range of business owners and customers.

Total Living Principles Score: 27 total / 84 possible

ENVIRONMENT	Score	ECONOMY	Score
Behaviors	3	Systemic View	1
Creation	3	Metrics	1
Durability	2	Benefits	3
Disassembly	0	Transparency & Truth	2
Supply Chain	1	Waste = Food	0
Waste	3	Product to Service	1
Total Env Score	**12**	**Total Econ Score**	**8**

PEOPLE	Score	CULTURE	Score
Impacts	0	Visions	3
Conflicts	0	Meanings & Reactions	0
Desirability	2	Systemic View	0
Need / Use	1	Diversity	0
Long View	1		
Total People Score	**4**	**Total Culture Score**	**3**

Scoring Key

0: Doing nothing

1: Exploring concepts

2: Implementing solutions

3: Exhibiting leadership

4: Achieving restoration

Graphics courtesy AIGA, The Living Principles for Design

Assessing Sustainability with the UN Sustainable Development Goals

This project is closely connected to 4 of the 17 goals laid out by the United Nations:

Goal 8 **Decent Work and Economic Growth**

This project supports small and midsize businesses, which are a backbone of the United States economy.

Goal 9 **Industry, Innovation and Infrastructure**

This project fosters innovation by enabling the adoption of reusable packaging. Reusable packaging has the potential to create systems-level change, including new approaches to the systems and infrastructure used to deliver products to customers.

Goal 12 **Responsible Consumption and Production**

This project encourages businesses to consider the full impacts of the ways they package their products.

Goal 13 **Climate Action**

This project supports a key climate solution identified by Project Drawdown: reduced plastics.[35]

United Nations Sustainable Development Goals:

Goals Connected to this Project:

Graphics courtesy The United Nations at sdgs.un.org/goals

Reflection & Future Development

The main goal of this project was to create a tool that inspires business owners to take an action step toward implementing reusable packaging.

The LCA visualizer provides one piece of the puzzle: clear, accessible data that helps the user visualize and understand the positive impacts of reusable packaging. But, factual information alone does not usually motivate behavior change. It needs to be paired with compelling messaging that taps into social norms, encourages commitments, and/or appeals to emotions.[36]

To complete the puzzle, the tool will need to live within a broader reusable packaging resource that provides empowering and motivating content and messaging.

Ultimately, this tool is a step in the right direction. With more work, and presented within the right context, it can be part of a solution that empowers SMB owners to adopt reusable packaging.

AREAS FOR FUTURE DEVELOPMENT INCLUDE:

Focusing on the user journey
This project began to map out the experience of a business owner interested in reusable packaging. More focus should be placed on this during continued development of this tool and its accompanying resource: more robust and diverse user personas and a deeper understanding of business owners' motivations and pain points.

Defining packaging formats
While the mockups created for this project showed a pump bottle, the tool will allow users to test results for a variety of packaging formats. This list will need to be defined and should integrate options that cover all models of reuse (Refill at Home, Refill on the Go, Return from Home, Return on the Go). The top-level choice for users may need to shift from packaging format (e.g. pump bottle) to use case (e.g. packaging hand lotion). In that case, the tool could encourage users to consider alternative product formats that create sustainability benefits (e.g. shampoo bars, powdered detergent, concentrates).

Development of a broader reusable packaging resource
The LCA visualizer developed in this project is not intended to stand alone. Future development will focus on creating a surrounding reusable packaging resource (most likely in the form of a website, as outlined in this project). Again, a deeper understanding of user journeys, needs, motivations, and barriers will be essential to developing clear, helpful, and motivating content. This work will include the development of branding and messaging for the resource and LCA tool.

Continued focus on behavior change
While the LCA visualizer is focused on data, the broader resource that it nests within will focus on clear, accessible information and empowering, solution-oriented messaging to support behavior change.[37]

Integration of extended producer responsibility (EPR) legislation support
Guidelines for how SMBs can adapt to EPR legislation will be an essential piece of the broader reusable packaging resource. There is potential to make connections between that information and the metrics presented in the dashboard.

Appendix

APPENDIX

Lifecycle Assessment Results: Sustainable Minds Overview

Reference Concept: Single-Use HDPE Bottle

12 mPts per 1 year of use

0.5 x 1 year of use
5.8 mPts
Estimate

Polyethylene, HDPE, granulate
Fossil fuel depletion
Manufacturing

Impact category	%
Ecological damage	
Acidification	3.3
Ecotoxicity	4.34
Eutrophication	1.22
Global warming	23.32
Ozone depletion	0.05
Resource depletion	
Fossil fuel depletion	33.16
Human health damage	
Carcinogenics	25.19
Non carcinogenics	3.05
Respiratory effects	2.53
Smog	3.84

Reusable HDPE Bottle

87% performance improvement

1.5 mPts per 1 year of use

4 x 1 year of use
5.8 mPts
Estimate

Polyethylene, HDPE, granulate
Fossil fuel depletion
Manufacturing

Impact category	%
Ecological damage	
Acidification	3.32
Ecotoxicity	4.36
Eutrophication	1.25
Global warming	23.36
Ozone depletion	0.05
Resource depletion	
Fossil fuel depletion	32.95
Human health damage	
Carcinogenics	25.24
Non carcinogenics	3.09
Respiratory effects	2.56
Smog	3.84

Reusable 50% PCR PP Bottle

86% performance improvement

1.6 mPts per 1 year of use

3 x 1 year of use
4.9 mPts
Estimate

Polypropylene, 50% virgin 50% recycled granlute
Fossil fuel depletion
Manufacturing

Impact category	%
Ecological damage	
Acidification	3.79
Ecotoxicity	4.04
Eutrophication	1.78
Global warming	24.55
Ozone depletion	0.06
Resource depletion	
Fossil fuel depletion	27.52
Human health damage	
Carcinogenics	26.84
Non carcinogenics	4.05
Respiratory effects	2.87
Smog	4.5

Reusable PLA Bottle

74% performance improvement

3.1 mPts per 1 year of use

3 x 1 year of use
9.2 mPts
Estimate

Polylactide, granulate, PLA (NatureWorks Nebraska)
Carcinogenics
Manufacturing

Impact category	%
Ecological damage	
Acidification	2.48
Ecotoxicity	10.39
Eutrophication	11.87
Global warming	17.33
Ozone depletion	0.05
Resource depletion	
Fossil fuel depletion	12.58
Human health damage	
Carcinogenics	28.54
Non carcinogenics	12.47
Respiratory effects	1.8
Smog	2.48

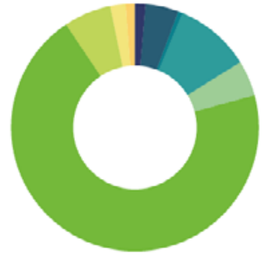
Reusable Aluminum Bottle

42% performance improvement

6.7 mPts per 1 year of use

5 x 1 year of use
33 mPts
Estimate

Aluminium, production mix
Carcinogenics
Manufacturing



Impact category	%
Ecological damage	
Acidification	1.36
Ecotoxicity	4.31
Eutrophication	0.59
Global warming	9.89
Ozone depletion	0.01
Resource depletion	
Fossil fuel depletion	4.65
Human health damage	
Carcinogenics	69.78
Non carcinogenics	6.18
Respiratory effects	2.03
Smog	1.21

Lifecycle Form: Reusable Recycled Polypropylene Pump Bottle

Component	Natural Environment	Raw Material Extraction			Material Processing			Component Manufacturing			Assembly & Packaging		
	Where does it come from?	Virgin Material	Input/ Output	Detail	Process	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Reusable plastic pump bottle: 100% recycled polypropylene bottle with recyclable pump (recycled polypropylene, virgin polypropylene)	Shale formations, sandstone beds, coal seams, oil deposits	**Natural Gas**	Input	Energy and equipment for extraction via fracking (most common form of natural gas extraction in the U.S.) (source)	**Natural Gas Liquids (NGLs) Separation**	Output	Propane is separated from natural gas	**Injection blow molding**	Input	Energy (electricity, fossil-fuel generated) and materials (e.g. stainless steel) used at the manufacturing facility	**Heat embossing**	Input	Energy (electricity, fossil-fuel generated) and materials (e.g. stainless steel) used at the manufacturing facility
			Input	Materials and energy to build natural gas pipelines		Input	Energy: NGL separation is an energy-intensive process		Input	100% recycled polypropylene pellets		Output	Embossed polypropylene bottle
			Input	Water, sand, chemicals used in fracking (commonly methanol, ethylene glycol, and propargyl alcohol)		Output	Contaminated water (sulfur and other impurities) requiring disposal		Output	100% recycled polypropylene bottle		Output	CO2 emissions from energy use during processing
			Output	CO2 emissions (methane released during extraction, emissions created by energy use)		Output	CO2 and methane emissions from leaks and from energy used for processing		Output	CO2 emissions from energy use during processing		Output	Material waste during processing (rejects, etc.)
			Output	Environmental degradation and habitat loss (extraction, pipelines)	**Steam Cracking (Propane)**	Output	Steam cracking of propane creates ethylene, propylene, methane, hydrogen gas	**Unknown process**	Input	Energy, materials			
			Output	Contaminated wastewater, including contaminated groundwater and drinking water (source)		Input	Energy: steam cracking is the most energy-intensive process in the chemical industry (source)		Input	Virgin and recycled polypropylene pellets			
			Output	Groundwater depletion (source)		Output	CO2 emissions: steam cracking is a major source of direct CO2 emissions from the petrochemical industry (source)		Output	Bottle pump assembly (actuator, closure, gasket, housing, dip tube)			
			Output	Health impacts for workers & communities (respiratory, neurological, cardiovascular, endocrine disruption, birth defects, cancer, premature mortality) (source)	**Chain-growth polymerization (Propylene)**	Output	Polypropylene is created by processing propylene via chain-growth polymerization		Output	CO2 emissions from energy use during processing			
			Output	Air pollution (benzene, toluene, ethylbenzene, and xylene; PM2.5; hydrogen sulfide; silica dust; nitrogen oxides and VOCs) and smog (source)	**Recycling of polypropylene**	Input	Energy and materials to construct and operate recycling facilities						
						Input	Energy for transportation of recyclable and recycled materials						
						Output	Microplastics and nanoplastics released in air and wastewater (source)						
						Output	Release of harmful chemicals present in virgin plastics and/or created during the recycling process (e.g. endocrine-disrupting chemicals, dioxins) (source)						
						Output	Unsafe conditions for workers handling recycling, especially recycling sent to other countries for processing (source)						
						Input	Additives to maintain quality (thermal stabilizers, UV stabilizers, nucleating agents, antioxidants, pigments, and more) (source)						

Lifecycle Form: Reusable Recycled Polypropylene Pump Bottle (continued)

Transport/Distribution/Purchase			Use Phase			Maintenance/Upgrading			End of Life Scenarios		
	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Shipping of bottles to warehouse for fulfillment	Input	Energy (gas/diesel) for transportation	**Container cleaning**	Input	Water, cleaning agent (e.g. dishwashing soap)	N/A		Bottle and pumps cannot be repaired or upgraded. Customers can purchase a replacement pump if needed.	**Reuse**		Bottles and pumps can be reused and refilled by individuals at home (refill at home model of reusable packaging) — see impacts of reuse under "Use Phase"
	Input	Materials used to construct and maintain transportation equipment		Input	Energy (electricity, fossil-fuel generated) to heat water and dry containers				**Material Recycling**	Input	Energy and materials to construct and operate recycling facilities
	Input	Materials (e.g. cardboard, paper tape) for shipping containers		Output	CO2 emissions					Input	Energy for transportation of recyclable and recycled materials
	Output	CO2 emissions and air pollution from gas-powered transportation vehicles		Output	Potential creation of microplastics during container use and cleaning					Output	Microplastics and nanoplastics released in air and wastewater (source)
	Output	Used shipping containers (potential for recycling)								Output	Release of harmful chemicals present in virgin plastics and/or created during the recycling process (e.g. endocrine-disrupting chemicals, dioxins) (source)
Order fulfillment (direct-to-consumer via online purchase)	Input	Energy (gas/diesel) for transportation								Output	Unsafe conditions for workers handling recycling, especially recycling sent to other countries for processing (source)
	Input	Materials used to construct and maintain transportation equipment								Input	Additives to maintain quality (thermal stabilizers, UV stabilizers, nucleating agents, antioxidants, pigments, and more) (source)
	Input	Materials (e.g. cardboard, paper tape) for shipping containers							**Landfill**	Input	Municipal solid waste
	Output	CO2 emissions and air pollution from gas-powered transportation vehicles								Output	Landfill gas (methane and CO2)
	Output	Used shipping containers (potential for recycling) *potential to use reusable shipping cartons*								Output	Leachate, potentially creating groundwater contamination
										Output	Environmental degradation and habitat loss
										Input	Energy for transportation
										Output	CO2 emissions from transport vehicles and on-site equipment

Lifecycle Form: Reusable Aluminum Pump Bottle

Component	Natural Environment	Raw Material Extraction			Material Processing			Component Manufacturing			Assembly & Packaging		
	Where does it come from?	Virgin Material	Input/ Output	Detail	Process	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Reusable aluminum pump bottle: aluminum bottle with recyclable pump (recycled polypropylene, virgin polypropylene); bottle is lined with BPA-free epoxy resin	Shale formations, sandstone beds, coal seams, oil deposits	**Natural Gas**	Input	Energy and equipment for extraction via fracking (most common form of natural gas extraction in the U.S.) (source)	**Natural Gas Liquids (NGLs) Separation**	Output	Propane is separated from natural gas	**Impact extrusion, necking**	Output	Aluminum bottle	**UV printing**	Output	Printed aluminum bottle
			Input	Materials and energy to build natural gas pipelines		Input	Energy: NGL separation is an energy-intensive process		Input	Energy (electricity, fossil-fuel generated) and equipment used at the manufacturing facility		Input	Energy (electricity, fossil-fuel generated) and equipment used at the manufacturing facility
			Input	Water, sand, chemicals used in fracking (commonly methanol, ethylene glycol, and propargyl alcohol)		Output	Contaminated water (sulfur and other impurities) requiring disposal		Output	Aluminum		Input	UV inks (monomers, oligomers, pigments)
			Output	CO2 emissions (methane released during extraction, emissions created by energy use)		Output	CO2 and methane emissions from leaks and from energy used for processing		Output	CO2 emissions from energy use during processing		Output	Potential health impacts to workers from monomers in uncu
			Output	Environmental degradation and habitat loss (extraction, pipelines)	**Steam Cracking (Propane)**	Output	Steam cracking of propane creates ethylene, propylene, methane, hydrogen gas		Input	Water and cleaning detergent		Output	CO2 emissions from energy use during processing
			Output	Contaminated wastewater, including contaminated groundwater and drinking water (source)		Input	Energy: steam cracking is the most energy-intensive process in the chemical industry (source)		Input	BPA-free epoxy coating (bottle lining)		Output	Material waste during processing (rejects, etc.)
			Output	Groundwater depletion (source)		Output	CO2 emissions: steam cracking is a major source of direct CO2 emissions from the petrochemical industry (source)	**Unknown process**	Input	Bottle pump assembly (actuator, closure, gasket, housing, dip tube)			
			Output	Health impacts for workers & communities (respiratory, neurological, cardiovascular, endocrine disruption, birth defects, cancer, premature mortality) (source)	**Chain-growth polymerization (Propylene)**	Output	Polypropylene is created by processing propylene via chain-growth polymerization		Input	Virgin and recycled polypropylene pellets			
			Output	Air pollution (benzene, toluene, ethylbenzene, and xylene; PM2.5; hydrogen sulfide; silica dust; nitrogen oxides and VOCs) and smog (source)	**Recycling of polypropylene**	Input	Energy and materials to construct and operate recycling facilities		Input	Energy, equipment used at manufacturing facility			
						Input	Energy for transportation of recyclable and recycled materials		Output	CO2 emissions from energy use during processing			
	Sedimentary rock, more abundant in tropical and subtropical regions	**Bauxite**	Input	Energy and equipment for extraction via open-pit mining		Output	Microplastics and nanoplastics released in air and wastewater (source)						
			Input	Water		Output	Release of harmful chemicals present in virgin plastics and/or created during the recycling process (e.g. endocrine-disrupting chemicals, dioxins) (source)						
			Output	Habitat destruction and fragmentation and biodiversity loss created by open-pit mining and related infrastructure (source)		Output	Unsafe conditions for workers handling recycling, especially recycling sent to other countries for processing (source)						
			Output	Groundwater depletion (source)		Input	Additives to maintain quality (thermal stabilizers, UV stabilizers, nucleating agents, antioxidants, pigments, and more) (source)						
			Output	Contamination of soil and water (bauxite tailings, aka red mud) (source)	**Bayer Process**	Output	Alumina (aluminum oxide)						
			Output	Health and environmental toxicity created by heavy metals present in bauxite tailings (Technologically Enhanced Naturally Occurring Radioactive Material - TENORM) (source)		Input	Sodium hydroxide solution (lye)						
			Output	CO2 emissions		Input	Energy (fossil-fuels) to create high temperature and pressure						
						Output	Red mud containing TENORM (Technologically Enhanced Naturally Occurring Radioactive Material), requires special disposal in clay- or synthetic-lined impoundments (source)						
					Smelting (Hall-Héroult Process)	Output	Aluminum						
						Input	Energy: smelting is an energy-intensive process, likely using fossil-fuels						
						Output	CO2 emissions						
						Output	Air pollution (fluorocarbon byproducts)						

Lifecycle Form: Reusable Aluminum Pump Bottle (continued)

Transport/Distribution/Purchase			Use Phase			Maintenance/Upgrading			End of Life Scenarios		
	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Shipping of bottles to warehouse for fulfillment	Input	Energy (gas/diesel) for transportation	**Container cleaning**	Input	Water, cleaning agent (e.g. dishwashing soap)	N/A		Bottle and pumps cannot be repaired or upgraded. Customers can purchase a replacement pump if needed.	**Reuse**		Bottles and pumps can be reused and refilled by individuals at home (refill at home model of reusable packaging) — see impacts of reuse under "Use Phase"
	Input	Materials used to construct and maintain transportation equipment		Input	Energy (electricity, fossil-fuel generated) to heat water and dry containers				**Material Recycling**	Input	Energy and materials to construct and operate recycling facilities
	Input	Materials (e.g. cardboard, paper tape) for shipping containers		Output	CO2 emissions					Input	Energy for transportation of recyclable and recycled materials
inks	Output	CO2 emissions and air pollution from gas-powered transportation vehicles		Output	Potential creation of microplastics during container use and cleaning					Output	Microplastics and nanoplastics released in air and wastewater (source)
	Output	Used shipping containers (potential for recycling)								Output	Release of harmful chemicals present in virgin plastics and/or created during the recycling process (e.g. endocrine-disrupting chemicals, dioxins) (source)
Order fulfillment (direct-to-consumer via online purchase)	Input	Energy (gas/diesel) for transportation								Output	Unsafe conditions for workers handling recycling, especially recycling sent to other countries for processing (source)
	Input	Materials used to construct and maintain transportation equipment								Input	Additives to maintain quality (thermal stabilizers, UV stabilizers, nucleating agents, antioxidants, pigments, and more) (source)
	Input	Materials (e.g. cardboard, paper tape) for shipping containers							**Landfill**	Input	Municipal solid waste
	Output	CO2 emissions and air pollution from gas-powered transportation vehicles								Output	Landfill gas (methane and CO2)
	Output	Used shipping containers (potential for recycling) "potential to use reusable shipping cartons"								Output	Leachate, potentially creating groundwater contamination
										Output	Environmental degradation and habitat loss
										Input	Energy for transportation
										Output	CO2 emissions from transport vehicles and on-site equipment

Lifecycle Form: Reusable Bioplastic (PLA) Pump Bottle

Component	Natural Environment	Raw Material Extraction			Material Processing			Component Manufacturing			Assembly & Packaging		
	Where does it come from?	Virgin Material	Input/ Output	Detail	Process	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Bioplastic (PLA + wheat straw) bottle with recyclable pump (recycled polypropylene, virgin polypropylene)	Shale formations, sandstone beds, coal seams, oil deposits	**Natural Gas**	Input	Energy and equipment for extraction via fracking (most common form of natural gas extraction in the U.S.) (source)	**Natural Gas Liquids (NGLs) Separation**	Output	Propane is separated from natural gas	**Unknown process**	Output	Bottle pump assembly (actuator, closure, gasket, housing, dip tube)	**Heat embossing**	Input	Energy (electricity, fossil-fuel generated) and materials (e.g. stainless steel) used at the manufacturing facility
			Input	Materials and energy to build natural gas pipelines		Input	Energy: NGL separation is an energy-intensive process		Input	Virgin and recycled polypropylene pellets		Output	Embossed wheat-straw PLA bottle
			Input	Water, sand, chemicals used in fracking (commonly methanol, ethylene glycol, and propargyl alcohol)		Output	Contaminated water (sulfur and other impurities) requiring disposal		Input	Energy, materials		Output	CO2 emissions from energy use during processing
			Output	CO2 emissions (methane released during extraction, emissions created by energy use)		Output	CO2 and methane emissions from leaks and from energy used for processing		Output	CO2 emissions from energy use during processing		Output	Material waste during processing (rejects, etc.)
			Output	Environmental degradation and habitat loss (extraction, pipelines)	**Steam Cracking (Propane)**	Output	Steam cracking of propane creates ethylene, propylene, methane, hydrogen gas	**Injection molding**	Output	Wheat straw-PLA bottle			
			Output	Contaminated wastewater, including contaminated groundwater and drinking water (source)		Input	Energy: steam cracking is the most energy-intensive process in the chemical industry (source)		Input	Energy (electricity, fossil-fuel generated) and materials (e.g. stainless steel) used at the manufacturing facility			
			Output	Groundwater depletion (source)		Output	CO2 emissions: steam cracking is a major source of direct CO2 emissions from the petrochemical industry (source)		Input	Wheat straw plastic pellets			
			Output	Health impacts for workers & communities (respiratory, neurological, cardiovascular, endocrine disruption, birth defects, cancer, premature mortality) (source)	**Chain-growth polymerization (Propylene)**	Output	Polypropylene is created by processing propylene via chain-growth polymerization		Input	PLA pellets			
			Output	Air pollution (benzene, toluene, ethylbenzene, and xylene; PM2.5; hydrogen sulfide; silica dust; nitrogen oxides and VOCs) and smog (source)	**Recycling of polypropylene**	Input	Energy and materials to construct and operate recycling facilities		Output	CO2 emissions from energy use during processing			
						Input	Energy for transportation of recyclable and recycled materials						
	Soil, water (agriculture)	**Corn (conventionally grown)**	Input	Sunlight, water, farmland		Output	Microplastics and nanoplastics released in air and wastewater (source)						
			Input	Synthetic fertilizers and pesticides/herbicides		Output	Release of harmful chemicals present in virgin plastics and/or created during the recycling process (e.g. endocrine-disrupting chemicals, dioxins) (source)						
			Input	GMO seeds (corn is an annual crop)		Output	Unsafe conditions for workers handling recycling, especially recycling sent to other countries for processing (source)						
			Output	Agricultural waste (only corn kernels are used to product PLA) (source)		Input	Additives to maintain quality (thermal stabilizers, UV stabilizers, nucleating agents, antioxidants, pigments, and more) (source)						
			Output	Air pollution (fertilizers, pesticides)	**Wet Milling & Fermentation**	Output	Lactic acid used to create PLA						
			Output	Water pollution and nitrogen runoff leading to poor water quality (eutrophication, algal blooms)		Input	Energy (fossil fuel), water						
			Output	Groundwater depletion		Input	Corn kernels						
			Output	CO2 emissions (farm equipment, fertilizers, transportation)		Output	Lactobacillus bacteria (used in fermentation)						
			Output	Soil erosion and depletion, loss of biodiversity and habitat		Output	CO2 emissions						
			Output	Health impacts for farm workers & communities from pesticides & herbicides (e.g. cancer, neurological issues, endocrine disruption, acute symptoms) (source)	**Ring-opening polymerization**	Input	Lactic acid used to create PLA						
						Output	PLA pellets						
	Soil, water (agriculture)	**Wheat (conventionally grown)**	Input	Sunlight, water, farmland	**Cleaning & Lignin Extraction (Wheat Straw)**	Input	Wheat straw						
			Input	Synthetic fertilizers and pesticides/herbicides		Input	Bacteria (Rhodococcus jostii), which breaks down lignin						
			Input	Seeds (wheat is an annual crop)		Input	Energy (fossil fuel) and equipment						
			Output	Wheat straw (byproduct of wheat production used to product wheat straw plastics, typically a waste product)		Input	Water						
			Output	Air pollution (fertilizers, pesticides)		Output	Reduced agricultural waste + reduced burning of wheat straw						
			Output	Water pollution and nitrogen runoff leading to poor water quality (eutrophication, algal blooms)		Output	CO2 emissions						

Lifecycle Form: Reusable Bioplastic (PLA) Pump Bottle (continued)

Transport/Distribution/Purchase			Use Phase			Maintenance/Upgrading			End of Life Scenarios		
	Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail		Input/ Output	Detail
Shipping of bottles to warehouse for fulfillment	Input	Energy (gas/diesel) for transportation	**Container cleaning**	Input	Water, cleaning agent (e.g. dishwashing soap)	N/A		Bottle and pumps cannot be repaired or upgraded. Customers can purchase a replacement pump if needed.	**Reuse**		Bottles and pumps can be reused and refilled by individuals at home (refill at home model of reusable packaging) — see impacts of reuse under "Use Phase"
	Input	Materials used to construct and maintain transportation equipment		Input	Energy (electricity, fossil-fuel generated) to heat water and dry containers				**Industrial Composting**	Input	Energy and materials to construct and operate composting facilities
	Input	Materials (e.g. cardboard, paper tape) for shipping containers		Output	CO2 emissions					Input	Energy for transportation of compostable materials and finished compost
	Output	CO2 emissions and air pollution from gas-powered transportation vehicles		Output	Potential creation of microplastics during container use and cleaning					Output	Reduced landfill waste, reduced methane emissions from landfills
	Output	Used shipping containers (potential for recycling)								Output	Finished compost (used as a soil amendment to support healthy soils)
Order fulfillment (direct-to-consumer via online purchase)	Input	Energy (gas/diesel) for transportation								Output	Microplastics and other contaminants if non-compostable materials are sent to composting facilities
	Input	Materials used to construct and maintain transportation equipment							**Landfill**	Input	Municipal solid waste
	Input	Materials (e.g. cardboard, paper tape) for shipping containers								Output	Landfill gas (methane and CO2)
	Output	CO2 emissions and air pollution from gas-powered transportation vehicles								Output	Leachate, potentially creating groundwater contamination
	Output	Used shipping containers (potential for recycling) "potential to use reusable shipping cartons"								Output	Environmental degradation and habitat loss
										Input	Energy for transportation
										Output	CO2 emissions from transport vehicles and on-site equipment

APPENDIX

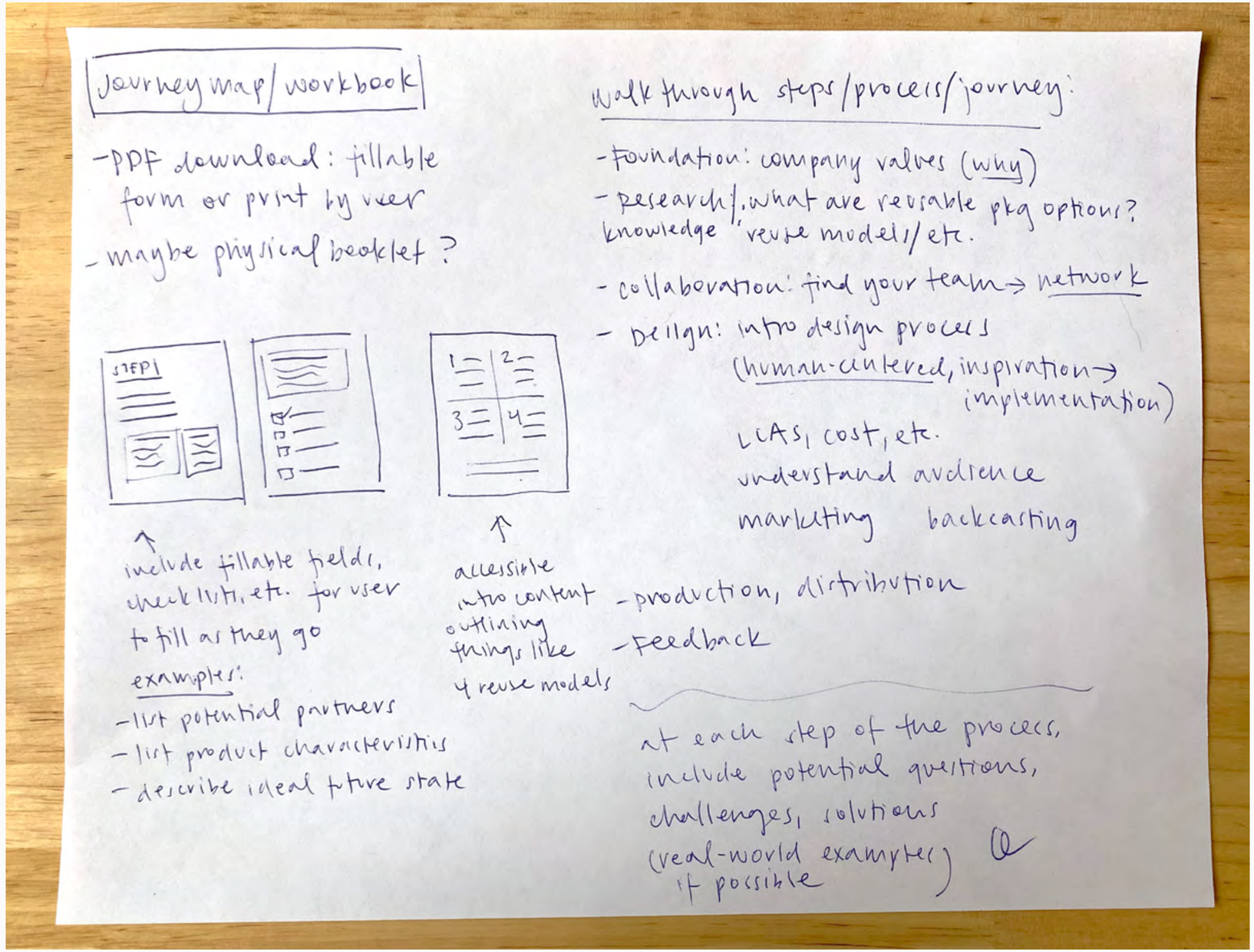
Early Concept Ideation: Workbook

Workbook walking SMB owners through the process/journey of adopting reusable packaging

- Guide through each step of the process, with opportunities to fill in their own info and work through questions along the way
- At each step of the process, include potential questions, challenges, and solutions (with real-world examples if possible)
- PDF download, fillable form and printable by user

POTENTIAL DESIGN FOR SUSTAINABILITY STRATEGIES:

- Create quality designs: human-centered, design for communication
- Design to encourage low-consumption behavior
- Optimize distribution systems



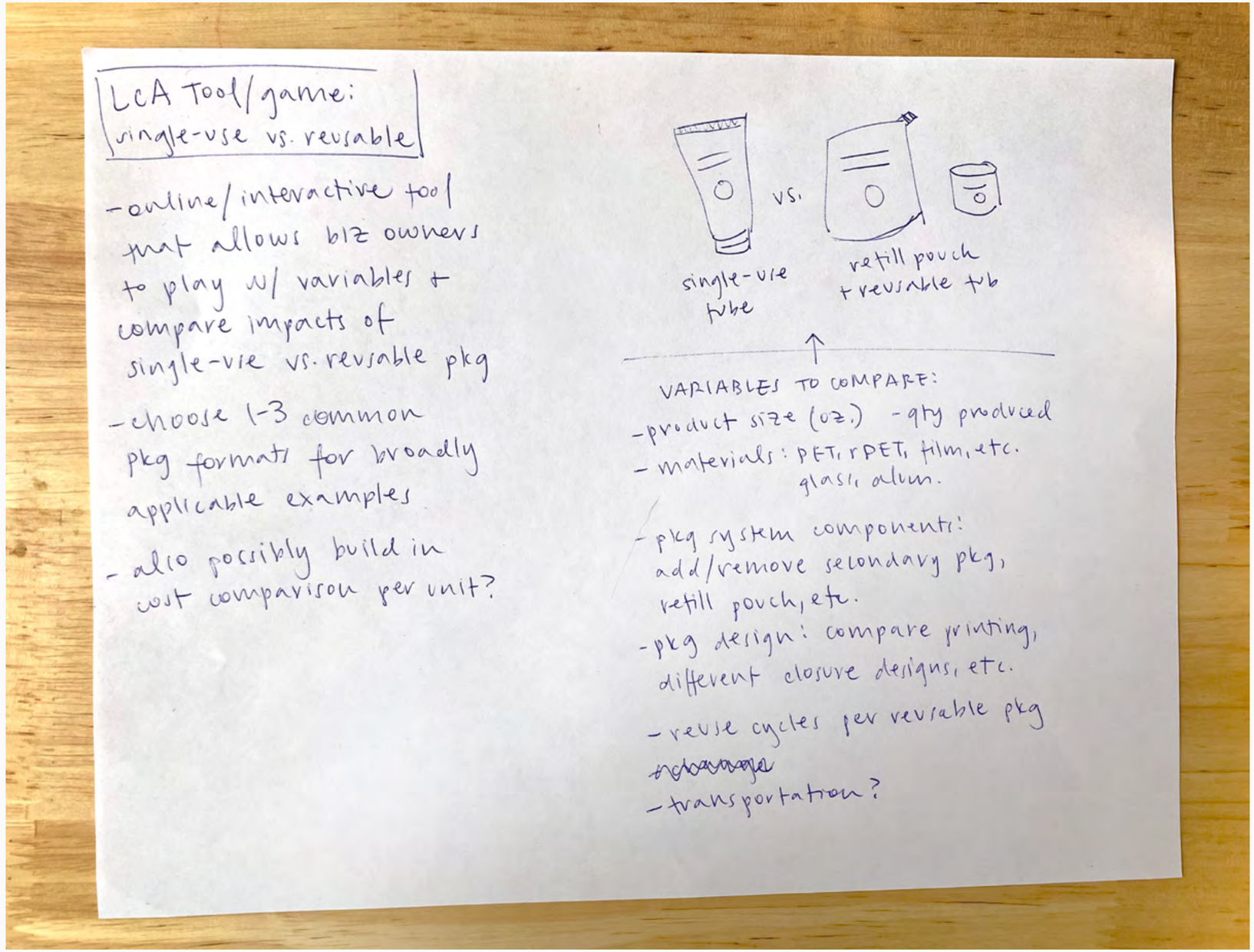
Early Concept Ideation: Interactive LCA Examples

Interactive LCA tool helps SMB owners understand the impacts of single-use vs. reusable packaging

- Choose 1 to 3 common packaging formats to compare single-use vs. reusable
- User is able to experiment with variables to see where the largest impacts (and potential reductions) come from
- Potentially include a cost comparison per unit
- Shared online (website)

POTENTIAL DESIGN FOR SUSTAINABILITY STRATEGIES:

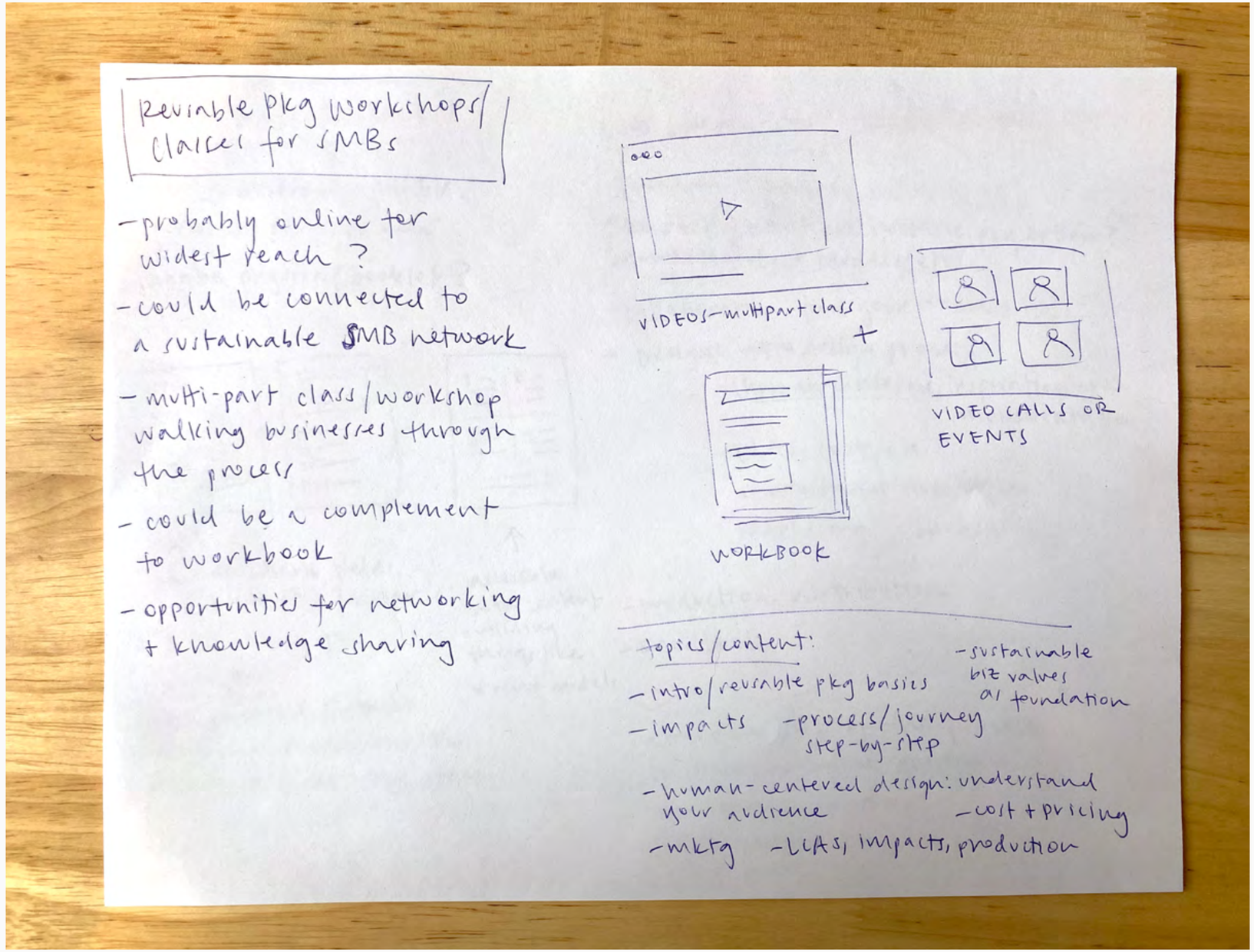
- Create quality designs: human-centered, design for communication
- Design to encourage low-consumption behavior
- Optimize distribution systems
- Conduct lifecycle analysis



Early Concept Ideation: Reusable Packaging Workshops for SMBs

Workshops/classes to guide SMB owners through the process of adopting reusable packaging

- Multi-part workshop walking business owners through each step of the process
- Create opportunities for networking & knowledge sharing
- Offered online: video classes, video calls, and possibly a digital workbook



POTENTIAL DESIGN FOR SUSTAINABILITY STRATEGIES:

- Create quality designs: human-centered, design for communication
- Design to encourage low-consumption behavior
- Optimize distribution systems
- Design to support networks

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