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4everPack

Final report

November 2023

Authors

4everPack was funded by Business Finland as a Co-Research project. The project took place 1.8.2021-30.9.2023, with overall budget 1,55m€. The project research group consisted of researchers from VTT Technical Research Centre of Finland and University of Vaasa. In addition, 14 companies funded the project and participated the project steering group in addition to taking part in project use-case demonstrations. Authors of this document want to express their gratitude to the actively participated companies for sharing their knowhow, participating the project workshopping and funding the project.

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4everPack

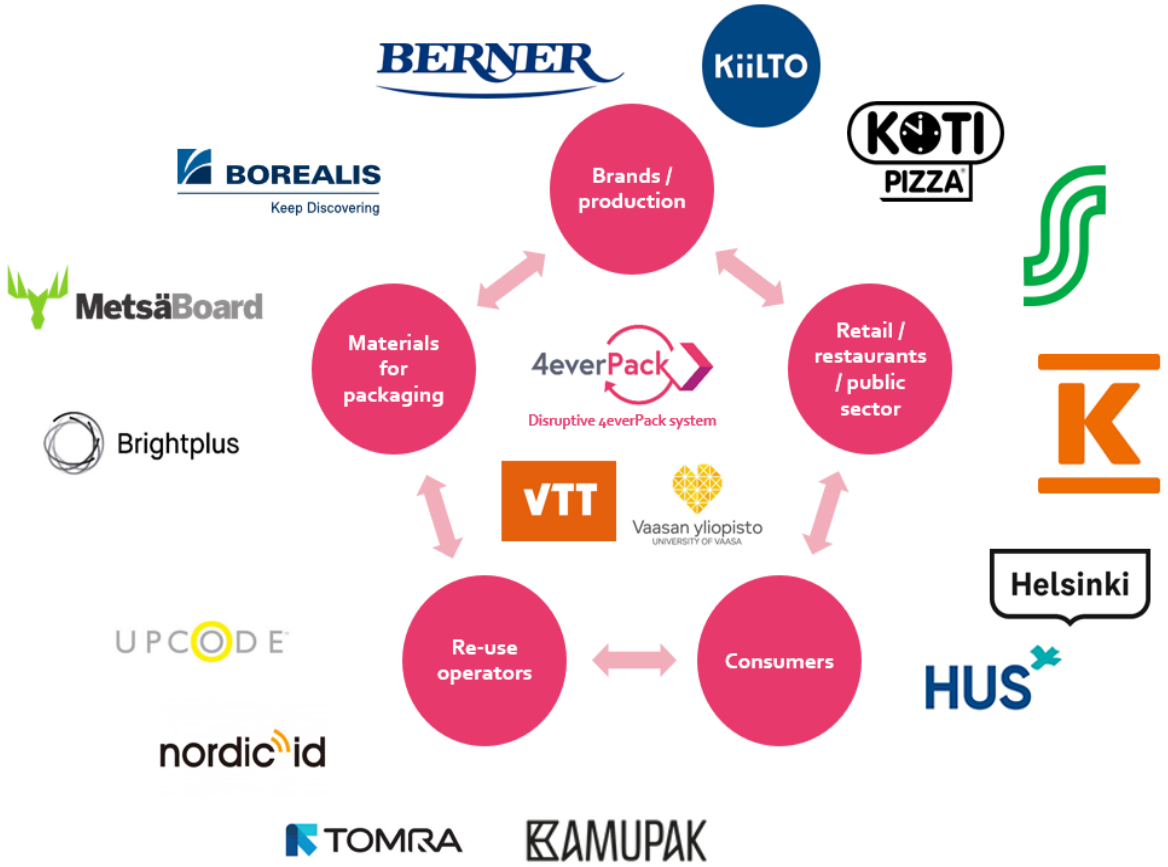
Executive Summary

The project

- 4everPack was a two year Business Finland research project aimed at generating understanding on packaging reuse in fast moving consumer goods (FMCG)

- The project observed reuse from multiple perspectives
  - Packaging materials (Wp1)
  - Packaging monitoring and traceability (WP2)
  - Reuse logistics (WP3)
  - European consumer acceptance (WP4)
  - Circular business models (WP5)

- The project consortia included VTT, University of Vaasa and 14 companies



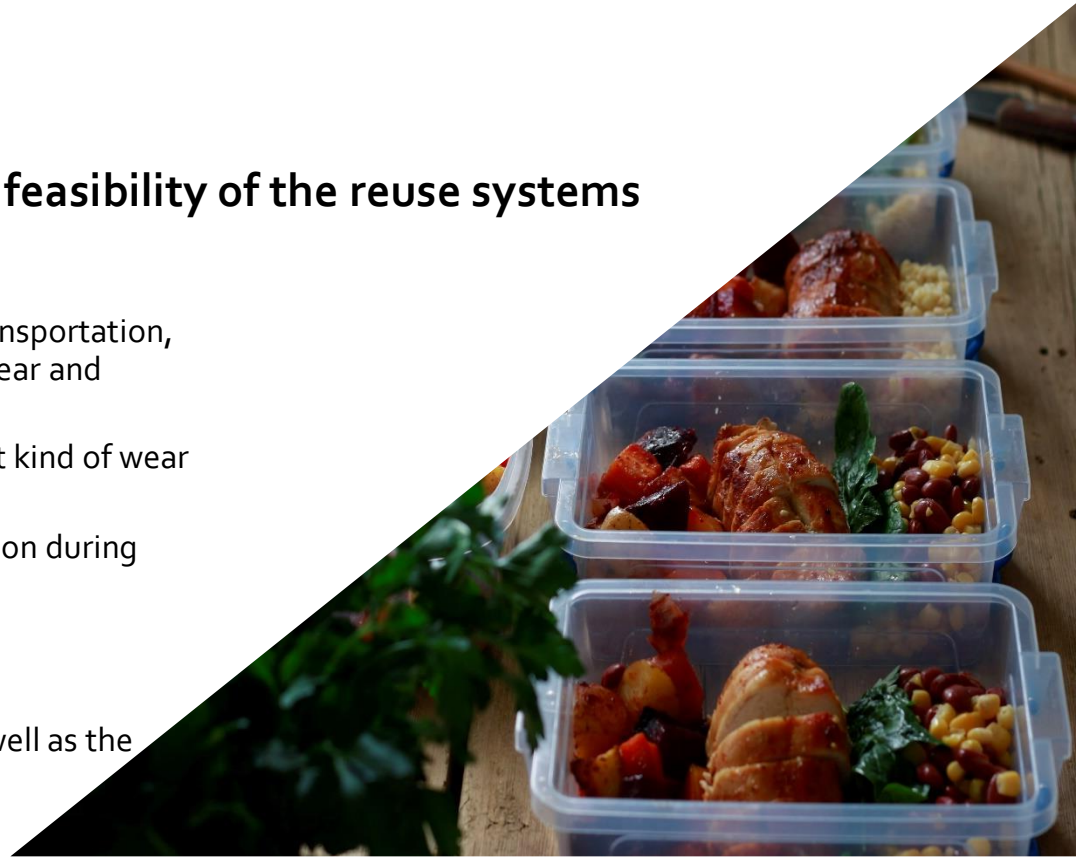
4everPack

Work packages key take aways

WP1: Material solutions for reusable packaging

1. **Materials are not the main hindering factor in setting up reuse systems, there are plenty of material options to produce suitable reusable packaging. Creating functional reusable packaging is more dependent on material and packaging design that meet the requirements of the product and reuse system.**
   - 3-step approach key:
     1. Design for use
     2. Design for reuse
     3. Design for recycling

2. **Number of reuse cycles however is a determining factor for overall feasibility of the reuse systems and it can be affected by material choices and design**
   - When reusable packaging is subjected to repeated use, handling, stacking, washing, and transportation, it may come into contact with various surfaces and experience frictional forces that cause wear and abrasion.
   - Packaging handling, especially in consumer use, seems to be a very important factor in what kind of wear the packaging endures.
   - Reusability can be enhanced by exploring additives use to mitigate material wear and abrasion during use.
   - The set-up created will support RDI in optimizing materials for reusable packaging.
   - Potential of washing as a maintenance/healing step could be investigated further.
   - More studies would be needed to study the effects of multiple washing-abrasion-cycles as well as the correlation between multiple use cycles and packaging condition/maximum cycles.



WP2: Packaging monitoring and traceability

- WP2 specified, developed and tested potential identification and **monitoring concepts for reusable packaging** and digital platform functionalities were defined together with technology developers and end users
- Different data carrier technologies, both visual and electronic, can be made durable and potentially recyclable to support individual identification of reusable packaging
- Condition monitoring capabilities can be combined with the data carrier technologies
- The most important digital platform functionalities include **identity management, stock management** and **incentives management**

WP3: Logistics solutions for reusable packaging

- WP3 Identified **supply chain alternatives** for three different reusable packaging use cases
  - The needs are case specific especially depending on the product type

- Missing activities, such as **collection and washing** of the reusable packaging need to be organized either by new or existing actors

- The simplest closed-loop supply chain solutions for reusable packaging require more effort from the consumer but can be set up by one actor

- The more advanced reusable packaging reverse supply chain requires planning, **infrastructure investments,** collaboration between supply chain actors and critical volumes for economies of scale

WP4: Consumer acceptance

- WP4 tackled the **European consumer acceptance** of reusable packaging in FMCGs

- **European consumers** hold **positive views, attitudes** and **intentions** toward reusable packaging

- Consumers **inherently associate** reusable packaging with **environmental sustainability**

- Environmental value **is not the main driver** of consumers' attitudes and intentions
  - **Affective factors** (emotional value and emotions) **predicted** attitudes and intentions and **resulted** from hypothetical choices and concrete product use (taste/use-induced emotions, warm glow)

- Reusable packaging can produce **intangible value** to consumers
  - Marketing highlighting emotional and social meanings of reuse in connection with env. sustainability might work as key marketing argument

WP5: Circular business models

- WP5 focused on the policy landscape of reusable packaging, developed circular business model through rapid experimentation, and highlighted sustainability hotspots.
- **Policy landscape:** Current EU and Finnish policy mixes set a good starting point for a systemic change.
- To ensure that Finland does not fall behind from other member states, further policy incentives, such as innovation policies and more stringent legislation, are needed to accelerate the transformation
- **5 use cases** were explored and circular business models were defined following a dedicated methodology.
- Assumptions related to the success of these business models were tested in a set of **rapid experiments** ranging from surveys, interviews, prototypes, field visits, and small pilots.
- A **roadmap** detailed key actions to be developed in the coming years to support the scale up of reusable packaging systems, with a focus on infrastructure, consumer engagement, technologies and policies.

Main take-aways

The transition to reusable packaging systems has the potential to reduce the negative environmental impact of single-use packaging. This transition however will need to be supported through:

- Technological advancements in connection to packaging materials, packaging design, traceability technologies
- Legislation resulting in paying of the real cost of the packaging (material use, cost of littering, cost of landfilling/incineration, cost of loss of biodiversity…)
- Investments / funding to innovate, experiment and scale reuse solutions in complex business ecosystems
- Increased consumer understanding and facilitation of reuse through concrete value propositions aligned with target consumers' preferences
- Supporting investments to build efficient reuse infrastructure

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Table of content

1. Introduction

Introduction

4everPack project was built to promote the business growth for Finnish companies and the export of reusable packaging in Fast Moving Consumer Good (FMCG) context. The project was expected to contribute towards reduction of FMCG packaging material use, use of fossil raw materials and to reduce waste generation and littering often related to single-use.

4everPack project worked as a window for Finnish companies to understand fundamentals of packaging reuse, understand the underlying benefits of packaging reuse and hence, help in opening opportunities for business development in this area.

4everPack Final Report collects the most important research outputs of the project in a simplified manner. Following chapters of the report will focus on:

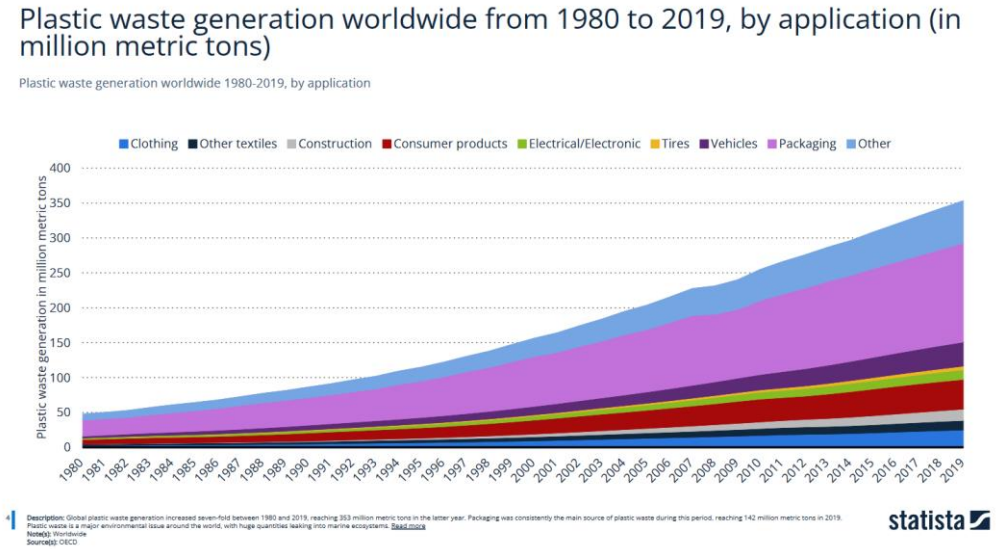
Context and objectives: the chapter introduces the operating area of the project as well as its key objectives the work were set to target.

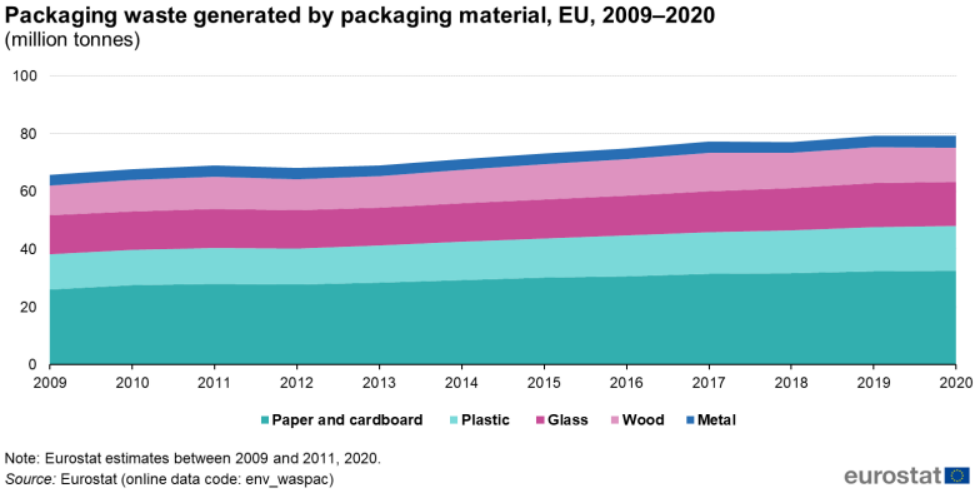
4everPack approach: the chapter discloses the special multidisciplinary focus that was selected in 4everPack project

WP related result chapters: The work package specific results are presented in more generous format, explaining the results in a wider context.

2. Context and objectives

Context: waste generation increase





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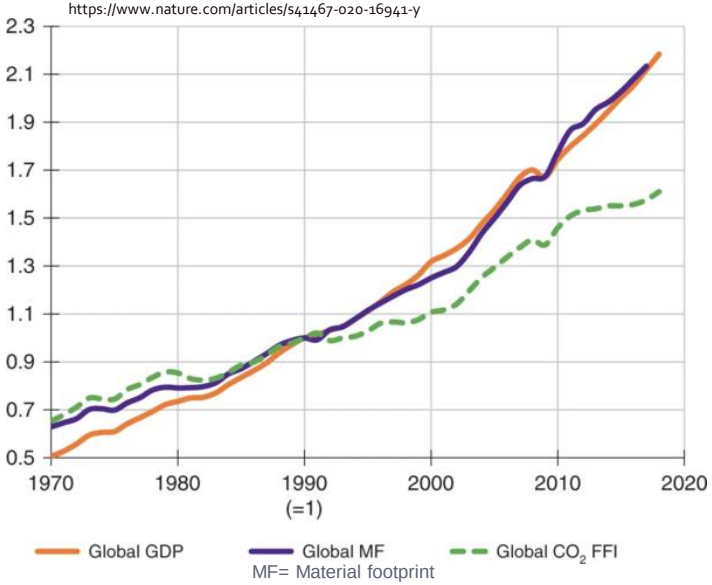
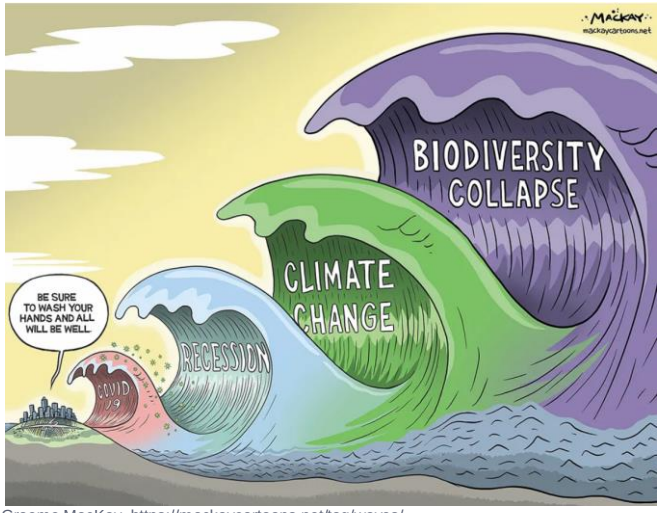


MF= Material footprint



Graeme MacKay, https://mackaycartoons.net/tag/waves/

Why packaging reuse?

- Properly managed* reuse system can
  - Shorten the packaging cycles: reuse cycles are shorter and more transparent than recycling cycles
  - Maintain the material quality & value and maintain the energy and effort put into producing packaging giving possibility to also reduce climate impacts
  - Reuse can reduce waste and contribute towards reduced littering & decoupling material use and growth
  - Reuse can potentially lead into more considerate consumption (shifting throwaway mindset/culture)
  - Reuse will not challenge food safety/shelf-life when done properly using best practices (e.g. restaurants, hotels, bottle reuse…)

* Properly managed reuse system will have an incentive for returning the packaging or bringing your own packaging along, it will have managed circulation including logistics and washing resulting in minimum impact at the end. It will also ensure rejected packaging recycling into new packaging,

3. 4everPack approach

What is 4everPack?

- **4everPack** is a project and consortium looking to answer how reusable packaging can be developed and scaled up and what benefits it can create for Finnish companies in FMCG business environment
- **4everPack** mission is to break reuse related myths and provide unbiased information to support the transition towards a circular economy for packaging
- **4everPack** is a Business Finland funded research project together with financing from 14 companies and two research organisations VTT & University of Vaasa
- **4everPack** duration 8/2021-9/2023

Illustration: Gregg Segal

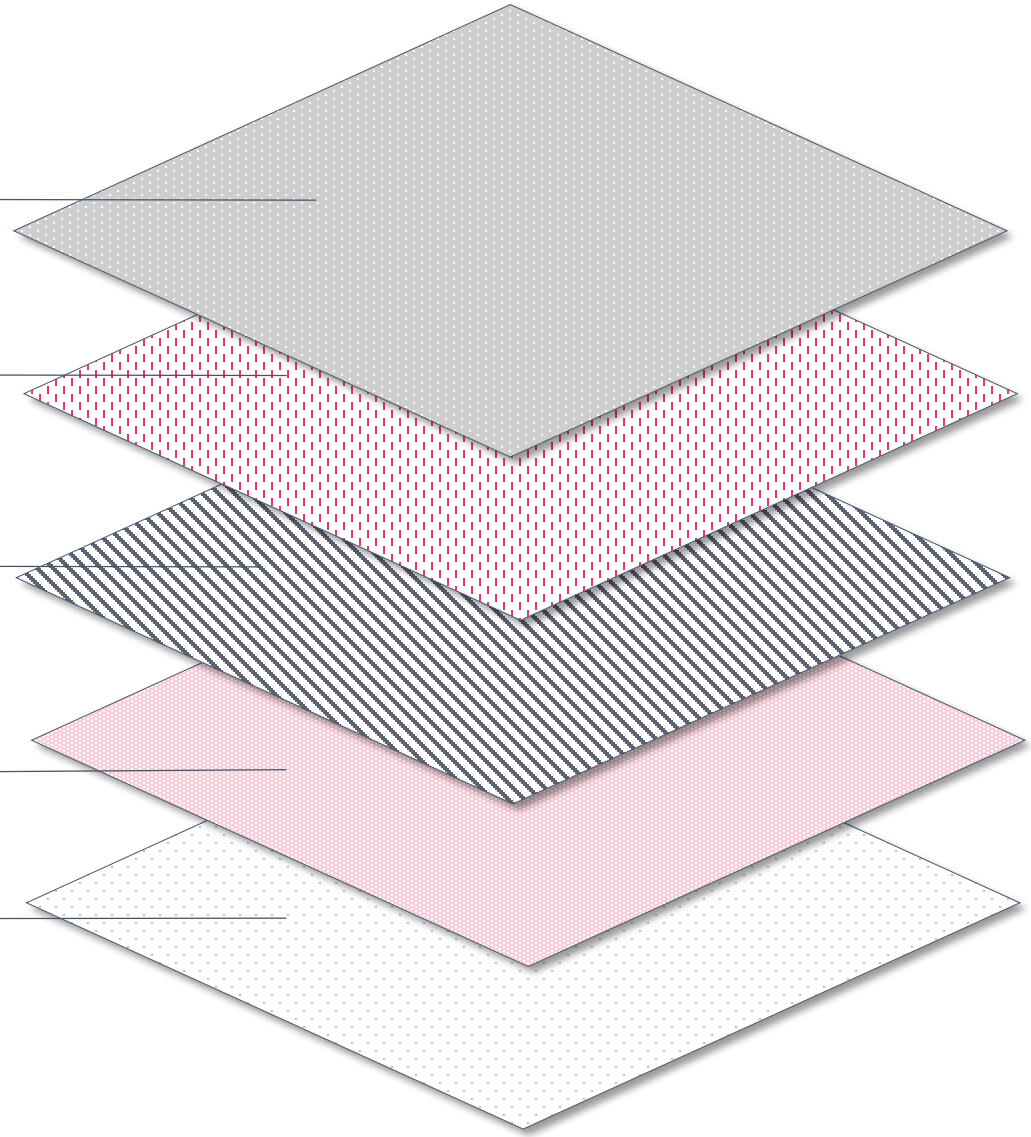
4everPack ecosystem

4everPack includes key representative stakeholders of the reusable packaging value chain

External collaboration / International collaboration

A multiscalar perspective

4everpack takes a multidisciplinary approach to study the different dimensions of reusable packaging systems



Business model innovation — *Feasibility / profitability/ Sustainability*

Consumer acceptance — *Desirability*

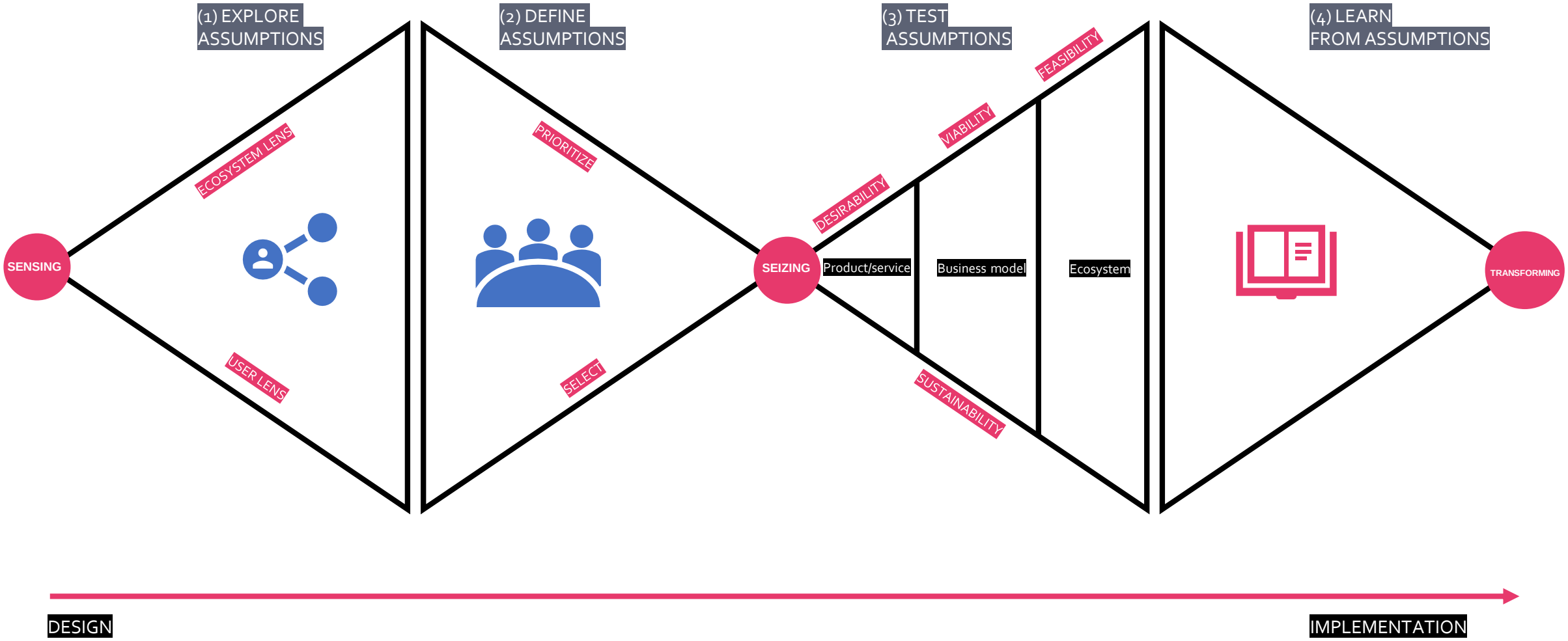
Logistics and value chain — *Cost effectiveness / reverse cycles*

IT tracking and tracing — *Monitoring*

Material innovation — *Durability / Safety /Recyclability*

A rapid experimentation approach

4everPack applies a rapid experiment approach to gather new insights on the different dimensions of reusable packaging systems.



Peer learning from use case experimentation

The research was built around 5 use cases (food / non-food reusable packaging) in which a portfolio of rapid experimentations were tested and implemented (surveys, interviews, field visits, pilots, prototyping).

4. WP1 Material solutions for reusable packaging

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WP1 overview

Material solutions for reusable packaging

Objectives:

1) **identify suitable available materials** and **processes** within plastic and paper-based packaging categories for **packaging reuse applications**,
2) **develop eco-design criteria** for packaging reuse applications, and
3) **carry out laboratory scale experiments for selected case studies** to further understand and support the safety and durability of reuse packaging materials.

Outcomes:

Outcome 1.1 Technical framework for reuse materials developed

Outcome 1.2 Ways to ensure and improve safety and safe use of reuse packaging

Outcome 1.3 Improved durability and reliability by counteracting material wear

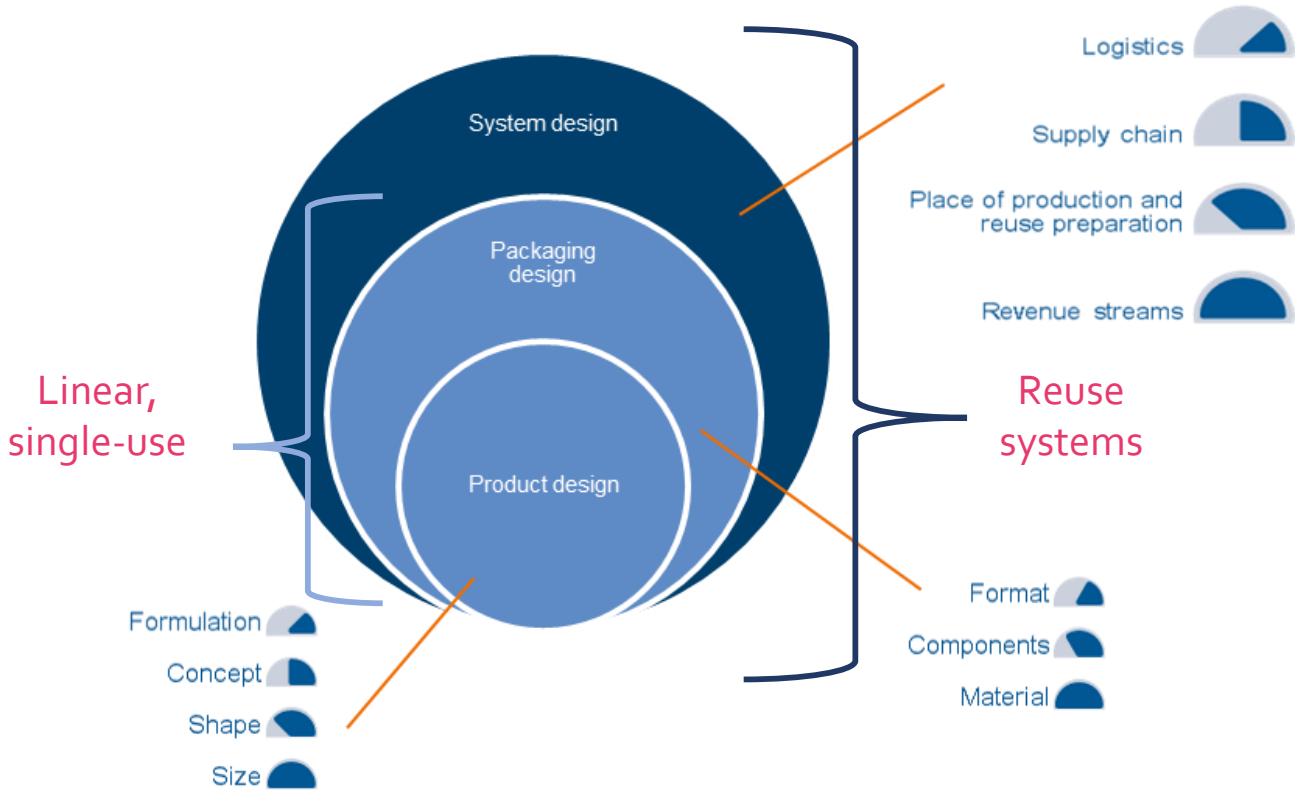
Operational environment report

- VTT Technology series, book/report published 03/2023:
  - Operational environment review for reusable packaging used in fast moving consumer goods
  - Link to publication
- Main findings from WP1 perspective:
  - Material choices and solutions for reuse applications typically follow the materials used for single-use packaging -> product requirements drive design and are typically not redesigned
    - Further advantages could be gained by redesign of product also -> e.g. remove of excess space, water
  - Reusable packaging faces requirements from both product and system
    - Reverse logistics, reuse related operations and maintenance, possibly intelligent elements such as sensors, and comms/marketing needs
  - Materials are not the main hindering factor in setting up reuse systems, material design can be done
  - Number of reuse cycles however is a determining factor for overall feasibility of the reuse systems
    - Reusable packaging tend to be more rigid (plastic) or lasting (metals)
    - As reusable packaging has higher value than single-use packaging, durability and added value could be gained from advanced materials like intelligent packaging, self-healing, self-cleaning, self-heating, self-cooling, etc.

Key takeaways from technical framework and ecodesign

03/11/2023

Designing reusable packaging vs. single-use packaging



Packaging types

1

Primary packaging

- Primary packaging is the packaging in direct contact with the product itself.
- The main purpose of primary packaging is to contain, protect and/or preserve the finished product, particularly against contamination.

2

Secondary packaging

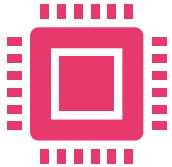
- Secondary packaging includes boxes or containers containing specific quantities of primary packages.
- Secondary packaging facilitates the handling of smaller products by collating them into a single pack. This type of packaging also provides supplementary protection to help maintain the integrity of the primary packaging
- Secondary packaging is frequently made up of multiple components (box, padding, separators, reinforcements, bags, paper

3

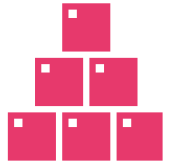
Tertiary packaging

- Tertiary packaging includes pallets and large shipping containers for storing and warehousing.
- Reusable transport packaging generally includes pallets, bins, tanks, intermediate bulk containers (IBCs), reusable plastic containers (RPCs) and other hand-held containers and totes, trays and dunnage

Innovative and emerging material solutions



Smart, intelligent and active packaging are packaging systems that integrate active and intelligent functions to the packaging, e.g. via sensors



The packaging sector is not currently utilising higher cost materials, but that is mostly due to the single-use nature of packaging and the fact, that with linear single-use systems, there is no reason to invest in expensive advanced materials.

The potential for reuse could be in utilising non-conventional packaging materials as the reuse packaging needs to withstand potentially more stress than typical single-use packaging due to multiple use cycles and reverse-logistics. E.g., self-healing, self-cleaning, antimicrobial, self-heating or –cooling materials.

Technologies for preparing packaging for new reuse cycles

Cleaning, sanitizing, sterilizing, disinfecting

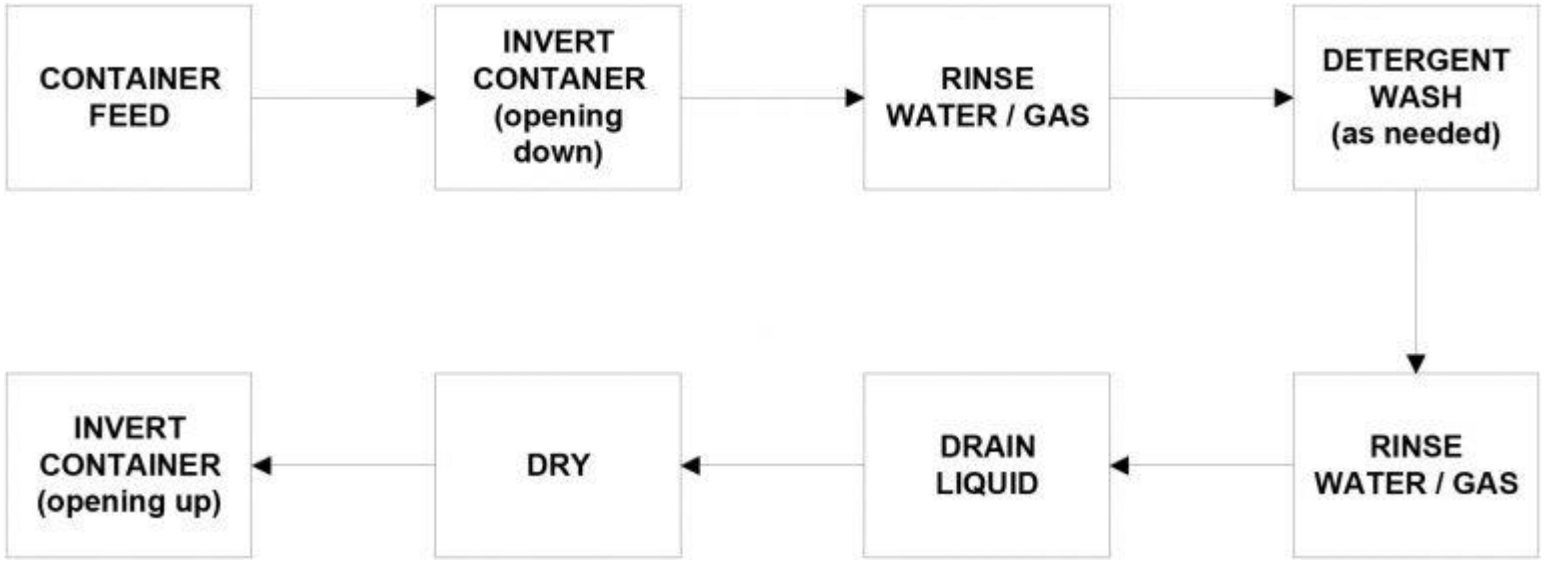
Cleaning	Sanitizing	Disinfecting	Sterilizing
• Removing dirt and debris from surfaces -> typically warm soapy water is used to physically remove impurities. Needs to be done prior to sanitizing or disinfecting. • Without a cleaning steps, physical and chemical hazards maybe left even with next steps	• Removes bacteria on the surfaces to a safe level. Used especially for food contact surfaces -> chemical concentration levels safe. • Typically chlorine bleach solutions are used, sodium hypochlorite is the active ingredient in chlorine.	• Kills majority of the pathogens like bacteria and viruses from surfaces = eliminating or reducing. • Disinfecting chemicals are typically the same as sanitizing, but more concentrated solutions. Also contact time may be longer (even up to 5-10 minutes).	• Kills all of the micro-organisms from surfaces. • E.g. irridation, which efficiently kills biological hazards.

Decontamination processes

Washing equipment / systems

Container-cleaning machines

- Container-cleaning machines are designed to clean the inside and/or the outside of containers using water, a water-based cleaning compound, air, steam, vacuum, or a combination.
- Continuous and batch operations.



Typical container-cleaning process

Dispensing systems and return machines for reuse

Main points to consider for automated return systems

***Location and network* of machines**

Needs to be considered carefully (e.g. security?), depending on locations also separate installation permits may be required

Deposit-based systems may be tampered or vandalised

Deposit scheme: digital credits

Methods to verify the correct packaging

Sensors, tags

Service and maintenance costs

Main points to consider for refill systems

Basic principles

Easy to use by staff and consumers

Quick to use

Minimize contamination and spillage.

Smart dispensers

Automation, better communication about the product and system, easier payments, consumer data

Location

Location of machines considered carefully (e.g. security?), depending on locations also separate installation permits may be required

Distributed sales points

Think about the *locations* of refill stations -> mobile or stationary, in a retail shop, public spaces, etc.

Service and maintenance costs

***Customised* dispensing systems**

Personalised product and desired quantity

Examples of dispensing systems and return machines for reuse

Vending machines for refill

One Less Bottle for shampoo and laundry detergants (liquids)

Re for liquid laundry detergants, shower and soap, shampoo and conditioner

Ecofill for cleaning products (gels, creams, liquids), modulard design (open access)

Vending machines for return

INSENSIV for coffee cups, beverage bottles, glass bottles and cups

Cuploop Solution automated deposit return for reusable packaging, utilises RFID chips

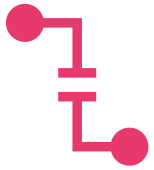
OZZI System, a closed-loop system for food packaging and collection system

Main points to consider for improving packaging safety with maintenance operations

Designing packaging and container cleaning system

Packaging design to support good washability

- Shape and form
- Materials chosen, surface properties
- Standardisation of packaging – e.g. bottles in standard sizes
- Container cleaning system



Maintenance

Tracking

Inspection and removal of damaged, contaminated, cracked

Repair

Minimizing risk of external contamination

Packaging maintenance: pay special attention to washing chemicals use

Three design layers for maximising safe circularity and sustainable circularity of reusable packaging

Design for use

Product formulation

Packaging:

- Durability
- Safety
- Appealing
- Easy to use

Design for reuse

Packaging (essential functions) -> (universal) design for operations efficiency

Packaging operations and maintenance -> system design

Design for recycling

Material choice to support recycling (polymer choices especially)

Packaging design to support recycling (e.g. multilayer materials)

Key results from experimental work

Safety and durability create reliability

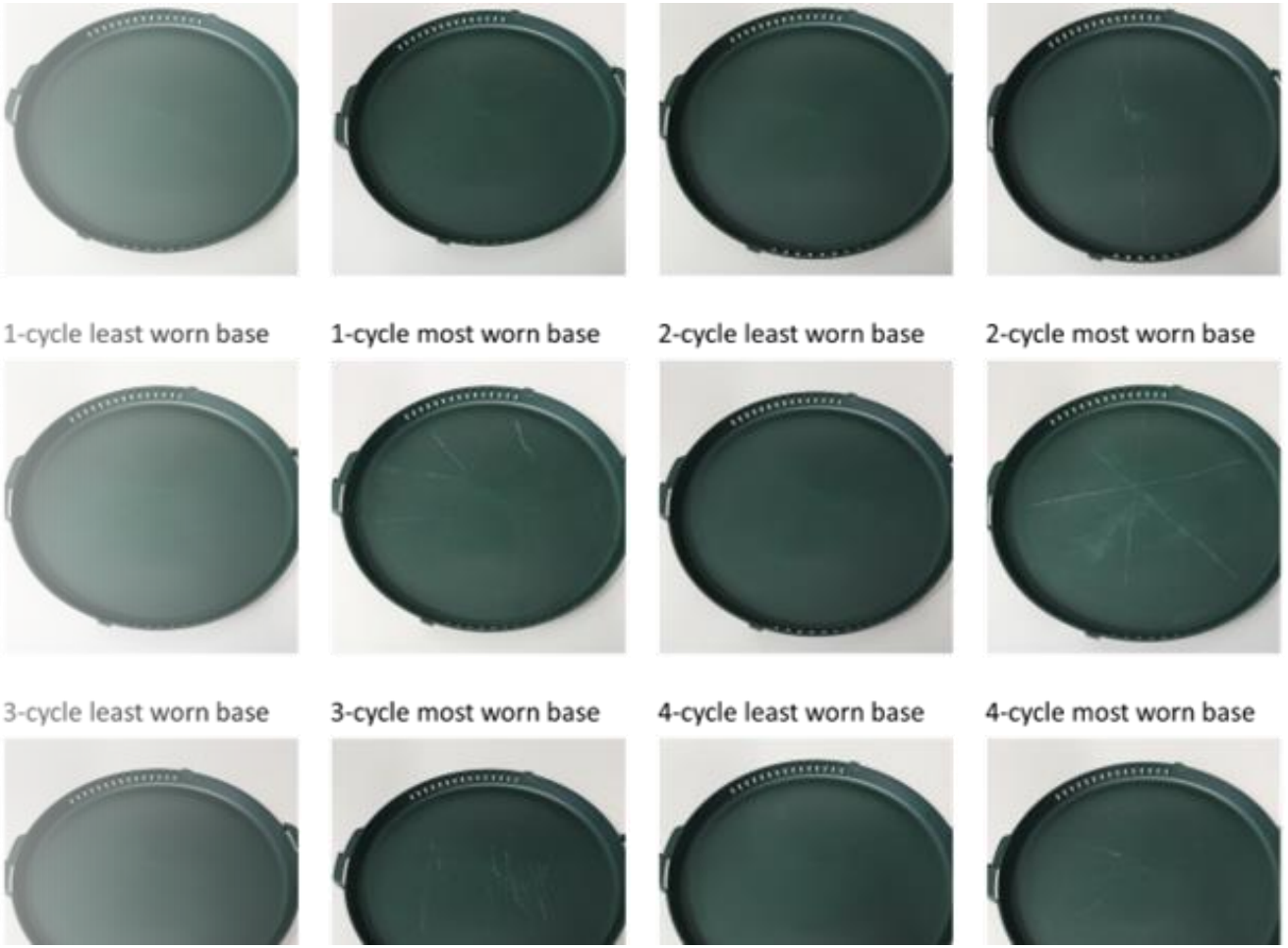
Safety and durability go hand-in-hand

Set of experiments

- Pizza box durability evaluation
- Scratch resistance and washability of material samples (PET, HDPE, 2xPP)
- Tag recyclability experiments

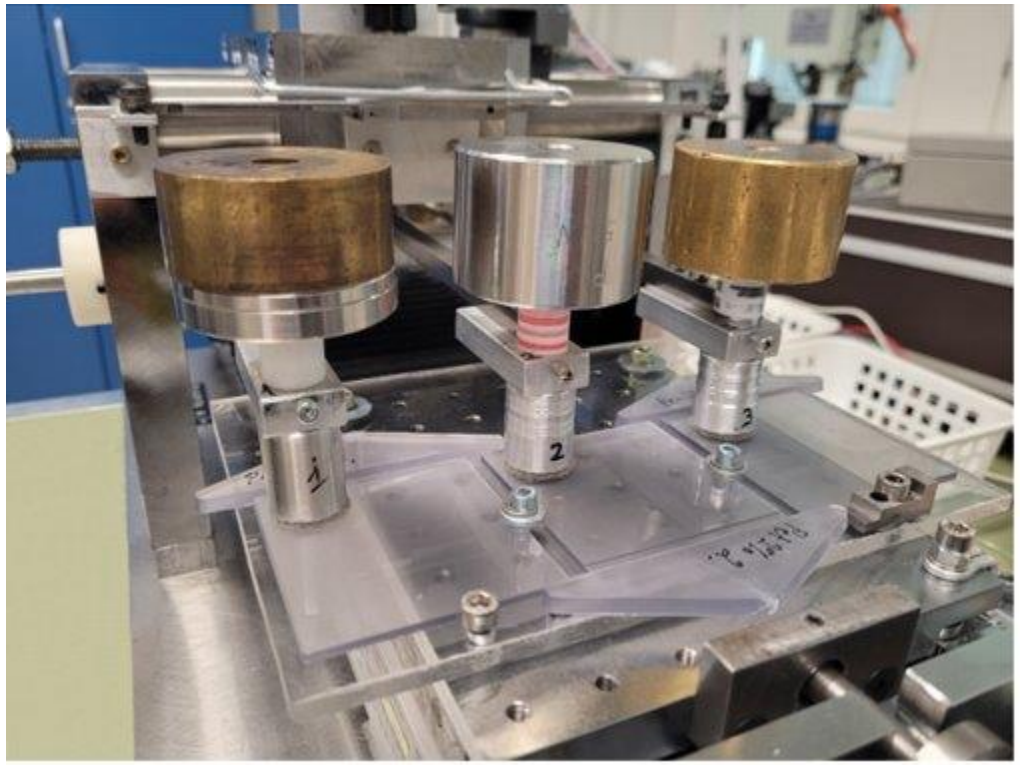
Pizza box durability: main conclusions

- At least with lower total amount of reuse cycles, the **packaging condition does not directly correlate** with the **amount use cycles**
- There seems to be a **stronger correlation** with **how the consumers (and sfaff) handle and use the packaging.**
- This highlights the **importance of educating** the consumers and staff in careful handling of the packaging.
- **More research** is needed to examine more packaging with multiple cycles to be able to determine what kind of a correlation there is between packaging wear and amount of reuse cycles. Most probably the increase in washing cycles coupled with scratching as more reuse cycles occur will wear of the packaging at an increased rate, yet this topic would need further research.



State-of-the-art tailormade scratch and washing test set-up developed at VTT

	Method
Phase 1	Micro-indentation measurements
Phase 2	Scratch tests
Phase 3	Reuse wear and washing mimicking experiment set up: 1.reciprocating wear test 2.washing 3.characterisation Repeated multiple times



Key findings:

- Polymeric reusable packaging may benefit from scratch and abrasion resistance additives, but more tailoring is needed for the specificity of wear of reusable reuse systems
- Washing conditions can determine if the washing wears the polymeric material further or if is can even act as a way to maintain packaging surface quality

Tag recyclability results

- Set-up: smart tags was mixed with PP film to investigate the effect of tags to mechanical properties
- Virgin plastics
  - The tag content seems to have minimal effect up to 10 w-%, but at 15 w-% it is already at 10 %
- Recycled plastics
  - The effect of tags seem to improve a little bit the impact strength at around 5 w-%, this is most likely due to the substrate PP-film with the tags
  - At already 10 w-%, the properties drop to 9 w-%
- Key takeaways
  - The mechanical properties drop quicker with the recyclates than virgin plastics.
  - In reality, the amount of tags that would end up in the recycling stream will be rather low in w-%
  - Hence, careful conclusions can be made that there is most likely no major effects to the recyclates' mechanical properties with small volumes of tags present
  - More studies could be made how the tag materials would get filtered in real scale recycling line operations, most likely they at least the inks could be filtered

Key takeaways from WP1

Plenty of options

Materials are not the main hindering factor in setting up reuse systems, material and packaging design can be done based on the requirements of the product and reuse system.

- 3-step approach key:
  1. Design for use
  2. Design for reuse
  3. Design for recycling

Durability = safety

Number of reuse cycles however is a determining factor for overall feasibility of the reuse systems

- When reusable packaging is subjected to repeated use, handling, stacking, washing, and transportation, it may come into contact with various surfaces and experience frictional forces that cause wear and abrasion.
- Packaging handling, especially in consumer use, seems to be a very important factor in what kind of wear the packaging endures.
- Reusability can be enhanced by exploring additives use to mitigate material wear and abrasion during use.
- The set-up created will support RDI in optimizing materials for reusable packaging.
- Potential of washing as a maintenance/healing step could be investigated further.
- More studies would be needed to study the affects of multiple washing-abrasion-cycles as well as the correlation between multiple use cycles and packaging condition/maximum cycles.

Meeting the system demands

System demands on the packaging – use of smart tags to enhance circulation in reuse and the effects on recycling

- Careful conclusions can be made that there is most likely no major effects to the recyclates' mechanical properties with small volumes of tags present.
- More tests would be need to done to determine how the microchips and inks may be filtered in real line operations.

5. WP2 Package monitoring and traceability

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WP2 overview

Package monitoring and traceability

Objective:

Identify, develop and evaluate technologies for pack age identification & location, condition and safety m onitoring

Outcomes

Outcome 2.1 Technologies available for package traceability and monitoring.

Outcome 2.2 Monitoring scenarios for reusable packaging.

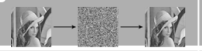
Outcome 2.3 Integrated solutions for re-usable package scenarios.

T2.1 Technologies available for package traceability and monitoring

Overview of technologies

- Tag section in Operational environments report

- Journal paper available in 2023
  - **Liisa Hakola, Elina Hakola, Sarianna Palola, Anna Tenhunen-Lunkka, Jussi Lahtinen.** *Durable and sustainable smart tags for identity management and condition monitoring: case study for reusable packaging and recyclable data carriers.* Packaging Technology and Science (Wiley), 2023.
  - Results for tag manufacturing and durability testing, discussion on tag recyclability

	1D bar code 	2D bar code 	Digital watermark 	RFID 	NFC 
Principle	Link to external database; product specific ID; 'EAN code'	Link to external database or information in code; error correction algorithms included; item or product specific ID;'QR code'	Information embedded into digital media; item or product specific ID; invisible to human eye	Electronic tag; passive or active; varying frequencies & reading distances available	Similar to RFID; short reading distance (0-4 cm)
Manufacturing / compatibility with packages	Printing / existing technology	Printing / existing technology	Printing / not widely used	Electronics manufacturing & printing / existing as labels	Electronics manufacturing & printing / existing as labels
Interpretation / decoding	Bar code reader	Bar code reader or app; smartphone compatible	Specialized reading app; smartphone compatible	RFID reader	NFC reader; smartphone compatible
Integration of monitoring capabilities	-	Possible as smart tags = integration of functional inks or indicators	-	Integration of sensors possible	Integration of sensors possible, e.g. chips with integrated T sensors available
Physical size	Scalable; depending on reading capabilities	Scalable; depending on reading capabilities; typically min. 1 cm x 1 cm	Scalable; depending on reading capabilities	Scalable; typically 1 cm x 1 cm onwards	Scalable; typically 1 cm x 1 cm onwards
Information capacity	<20 numerical characters	Up to ~7000 characters		Up to MB, typically ~2kB	Up to MB, typically ~2kB
Cost range	<1snt (printing ink)	<1snt (printing ink)	<1snt (printing ink)	>1 €	>1 €, but a few snt alternatives also available
Expected lifetime	(Theoretically) unlimited	(Theoretically) unlimited	(Theoretically) unlimited	12 months	12 months

T2.2 Monitoring scenarios for reusable packaging

Monitoring scenarios for reusable packaging

- Decision on tag technologies for experimental tests
  - Workshop with WP2 partners to specify monitoring needs
  - Discussions with the rapid experiment leaders to understand their monitoring needs
- Literature survey on machine vision for packaging industry
- Specification of two tag scenarios that could be used separately or jointly:

	Durable tag	Single-use tag
Purpose	Package identification	Content identification
Monitoring capabilities	No / Yes	Yes
Manufacturing	Embedded into package	Label / sticker

Machine vision for packages

Machine vision in packaging industry

- Quality of the raw materials
- Package inspection: e.g. closing, fill levels, item counts
- Package quality: e.g. detection of surface defects, wrinkles, streaks or holes
- Dimensions of shapes
- Label and print quality
- Barcode checking and reading
- Matching content and package

Machine vision for reusable packages

- Understanding of factors affecting hygiene: scratches, decolouring, microbes etc.
- Classification of packages
- Algorithm and model development

Technical requirements

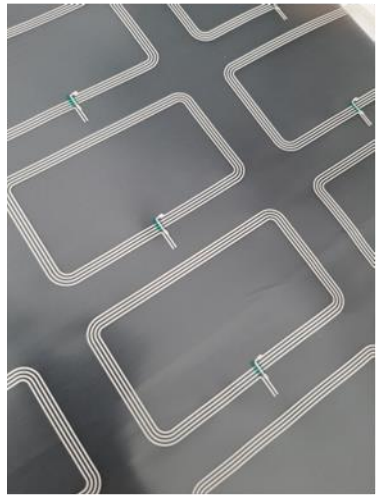
- Illumination = Lighting conditions
- A camera
- An image capture board
- Computer hardware
- Software combined with numerous algorithms and methods

T2.3 Integrated solutions for re-usable package scenarios

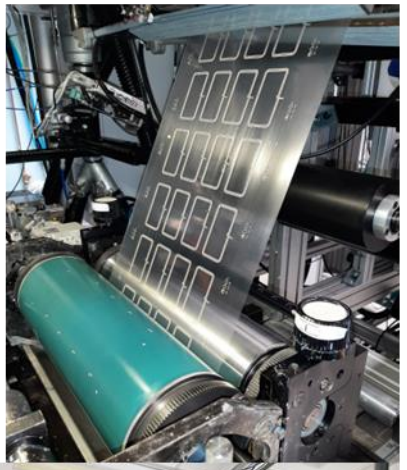
Integrated solutions for reusable package scenarios

- Experiments to test integration of tags into typical reusable packaging materials, and analyze durability of the tags
- Literature survey on tag recyclability combined with experiments in WP1
- Specification of a concept outline for digital platform functionalities
  - Based on regular meetings with key partners and discussions with rapid experiment owners

R2R printed antenna structures on PP



Rotary screen printing with ROKO



ROKO line

Experimental plan

- Substrates: PE & PP, later materials from WP1
- 2D barcode: UpCode
- RFID tags: Nordic ID & Kamupak/Confidex
- **Processes** to be tested
  - **Laser engraving** of 2D bar codes on package surface
  - **Overmoulding of** RFID tags & 2D bar codes (=embedding inside package)
  - **Protection** of RFID tags & 2D bar codes from wear (coating, lamination)
- **Monitoring** technologies to be tested
  - **Thermochromic ink** together with 2D bar code
  - **Integrated temperature sensor** with RFID tag (from Nordic ID)
  - **Time-temperature indicator (TTI)**
  - **Hygiene monitoring** based on machine vision (desktop study)
- **Conditions** to test: temperature changes, washing, microwave heating

RFID and NFC tags

- Passive or active electronic tag
- Varying frequencies & reading distances, monitoring capabilities
- NFC = short reading distance

2D bar codes: Data Matrix and QR Code

- Link to external database or information in code
- Error correction algorithms
- Item or product specific ID

Smart Tag

- Visible or electronics markers with sensing functions
- ID + monitoring

- **Functional inks** = printable inks that change their colour after exposure to certain conditions
- **Sensors** = devices detecting and responding to some type of input from the physical environment, output is a signal that is converted to human-readable display
- **Indicators** = sensors based on optical reading, complete systems

Materials used

Name	Specs	More information
Substrates		
PP Borealis	White	
PE Borealis	Clear	
PP Etra 1: Priplak Cristaline 000	0,91 g/cm³, clear, 800µm	https://www.etra.fi/fi/pp-kalvo-kirk-martio-800x1200x0-8mm-10540003379
PP Etra 2: Priplak Izilyss	0,91 g/cm³, white, 280µm	https://www.etra.fi/fi/pp-kalvo-valk-060-650x1100x0-28mm-10540003386
PE Etra: 150 015	Clear, 150 µm	https://www.etra.fi/fi/pe-kalvo-sukka-150-015-kirkas-10360003118
Water soluble film: Solublon TC	PVA water soluble film	TDS
PET	Melinex® PET ST506 125 µm	https://www.tekra.com/products/films/polyester-films/heat-stabilized-pet/melinex-st506
Paper	Stora Enso Novapress Silk 100 – 100 gsm	
Monitoring technologies		
Thermochromic ink: ChromaZone	Black 31°C, flexo printing, aqueous, reversible	MSDS
Thermochromic ink: CTI	Blue 47 °C, flexo printing, aqueous, reversible	MSDS
Thermochromic ink: Thermostar	Black 47 °C, flexo printing, aqueous, reversible	MSDS
Time-temperature indicator (TTI): WarmMark	WM 10/50, 100C 2/12/48h	https://www.linton.fi/production/temperature-indicators/?lang=en
RFID tags		
Confidex 1: Carrier Classic	73 mm x 8 mm	Data Sheet
Confidex 2: Carrier PRO	92 mm x 24 mm	Data Sheet
Confidex 3: High temperature resistant	73 mm x 8 mm	
Nordic ID standard (543.1)	~42 mm x 16 mm	
Nordic ID microwave (5066-3-1 F ETSI R6-P)	~94 mm x 14 mm	
Nordic ID Smartrac DogBone (472_1)	88 mm x 24 mm	NXP UCODE G2iL

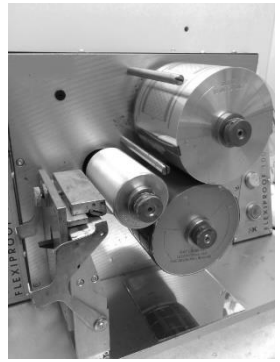
Methods

- Laser engraving: CO_2 laser on R2R DELTA line
- Over moulding: Engel Victory 120
  - Polypropylene (PP) RCP PPR9220 Total Energies
  - Cyclo-olefin-copolymer (COC)
  - TPE – Kraiburg
  - Polycarbonate (PC)
- Flexography printing: RK Flexiproof
- Screen printing: Baccini/EKRA printer
  - Silver ink: Asahi LS-411AW
  - Insulator ink: Loctite EDAG PF-455B
- Inkjet printing: Dimatix DMP-2850
  - Blue ink: Linx 6120 Food grade ink(LINX-6120) | Linx Printing Technologies Ltd. | 500 millilitres (B11560)
- Lamination by hand with two-sided tape + film (=lid)
- Lamination by DRYTAC JetMounter laminator
- Tolerance x 25 times
  - Temperature: 1 hour at 90 °C
  - Washing (water contact): 1 hour with detergent (NaOH 0.1 wt-%)
  - Microwave heating: 1 min. 800W

EKRA XH printer

DRYTAC JetMounter laminator

Dimatix



Flexiproof

Results summary

Tag type	Substrate	Method	Heating x1	Microwave x1	Washing x1
2D barcode	PE, PP	Laser	OK	OK	OK
2D barcode	Soluble film	Printing	-	-	OK (dissolves)
Smart tag	PE, PP	Lamination	OK	OK	NOK (ink dissolves)
Smart tag	PE, PP	UV coating	OK	OK	NOK (ink dissolves)
Smart tag	PE, PP	Overmoulding	OK	OK	OK
RFID	PP	Overmoulding	*Overmoulding not successful: no adhesion*		
RFID	COC	2K overmoulding	OK	OK	OK
Smart Tag	PE, PP	PET / barrier film / PE lamination[1]	-	-	OK
Smart Tag	PE, PP	Lid + tape[2]	OK	OK	OK
NFC	PET, PP, Paper	Printing + lid[3]	OK	OK	OK
RFID	PP	2K overmoulding	*Overmoulding not successful: tag destroyed or dislocated*		
RFID	PP, PET, OPP	Lid + tape[4]	OK	-	OK

1
- Hydrophobic Fluorepel 804
- PET film lamination, different tapes
- Barrier film and adhesive lamination
- 2-sided PE laminate

2
Lids:
- PET Melinex ST506 – 125 µm
- PET Lumirror – 36 µm
- Innovia OPP – 25 µm
- LD-PE – 30 µm

Tape: 3M 9774WL

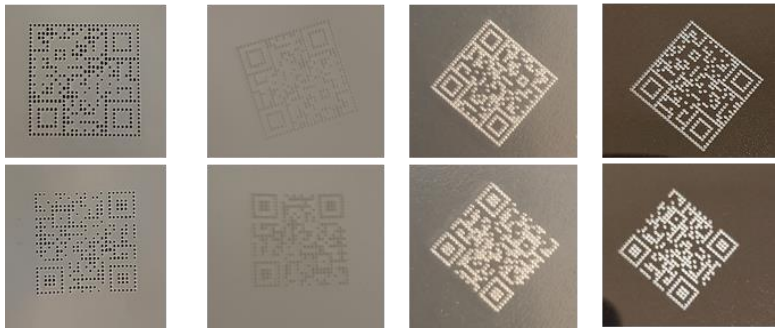
3
Lid: 100 µm PET foil
Tape:
- 3M 9774WL
- TESA 68562 PV40

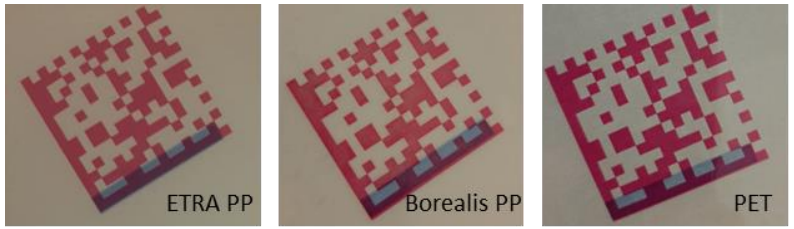
4
Lid:
- Borealis PP
- PET CT3 75 µm
- OPP 25 µm

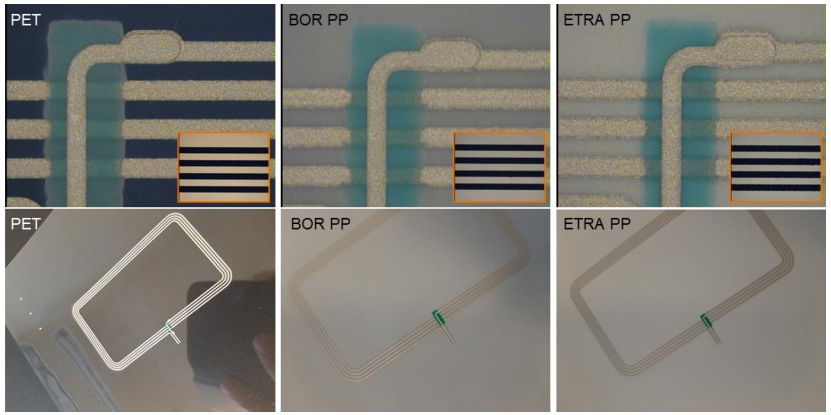
Tape:
- TESA 68562
- 3M 467

Durability testing 25 times

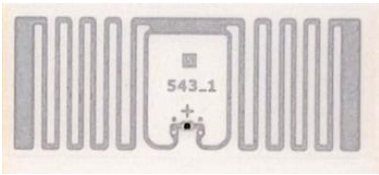
Tag type	Substrate	Method	Heating x 25	Microwave x 25	Washing x 25
2D barcode (10 samples)	PET, PP	Laser	OK	Not done due to microwave oven breakage	OK
Smart Tag (10 samples)	PET, PP	Printing + lid + tape[1]	OK		OK (Etra PP NOK after x4)
NFC (2-4 samples)	PET, PP	Printing + lid + tape[1]	OK		OK (PET NOK after x20)
RFID (4 samples)	PP	Lid[1]	OK		OK







1 Lid: PET Autostat CT3 (75 µm)
Tape:
- 3M 467
- TESA 68562 PV40



SWOT analysis for tag technologies

	Strengths	Weaknesses	Opportunities	Threats
Laser engraved 2D barcodes	• Durability • Substrate compatibility • Low price • Little effect on recyclability	• No monitoring capabilities • Visual reading dependent on contrast	• Wide package material selection	• Microbial growth in grooves
2D barcodes / Smart Tags with protective layer	• Monitoring capabilities • Low price • Established printing processes	• Visual reading • Moderate to high effect on recyclability depending on the material combinations of layers and packaging material	• Direct printing or label • Wide selection of monitoring capabilities	• Recycling with the protective layer • Availability of reversible vs. irreversible monitoring technologies
Overmoulded RFID tags	• Monitoring on chip • Electronic reading	• Microwave tolerance • Food contact • High price • Moderate to high effect on recyclability depending on the material combination of layer and packaging material	• Direct printing or label • Continuous monitoring	• Effect on package recycling
RFID / NFC tags with protective layer	• Monitoring on chip • Electronic reading	• Microwave tolerance • High price • Material dependent • Moderate to high effect on recyclability	• Continuous monitoring	• Disintegration of electronics at end-of-life

Digital platform functionalities

Management by package owner

Data carriers

Reading infrastructure

Integration with existing value chain platforms & access by users

Automated traceability and reporting tool

Functionalities
- Identity management
- Stock management
- Incentives management

Data
- Times of use
- Circulation speed
- Location
- Batch information
- Customer information

Digital platform in cloud

Recycling of tags

- Das, 2019, IDTechEx: *"21 billion packages sold in 2030 will contain an electronic feature to enhance the package"*

- **Laser engraved tags** should have no effect on package recycling
- **Electronic tags**
  - Direct printing
    - Disintegration of electronic material from package materials for material recovery
    - End up as general impurities or into repulping
  - Labels: Disintegration before package recycling
    - Labels directed to electronics recycling
  - Overmoulding: Disintegration difficult
    - End up as general impurities or into repulping
- **Smart tags** compatible with deinking processes
  - The effect of protective layer?

Aliaga, et al., 2015, Waste Manag. 28:41-8: *"Electronics are shown not to significantly increase the fibre rejects during paper recycling, and properties of the recycled paper, since blocked in the sieving systems to be disposed by burning or on landfill."*

Downsides

- Electronics materials and components lost from electronics circularity
- Increase in disposal costs

Hakola, et al, 2022, ECOtronics project final report (www.ecotronics.fi): *"From plastics waste electronics could be separated during the washing process before extrusion and be potentially recovered from the rejects. However, suitable methodologies do not yet exist."*

WP2 key take aways

- Different data carrier technologies, both visual and electronic, can be made durable and potentially recyclable to support individual identification of reusable packaging
- Condition monitoring capabilities can be combined with the data carrier technologies
- The most important digital platform functionalities include identity management, stock management and incentives management

Image source: unsplash.com

6. WP3 Logistics solutions for reusable packaging

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WP3 overview

Logistics solutions for reusable packaging

Objectives

Identify the most sustainable and cost-efficient logistic solution for reusable packaging system

Outcomes

Outcome 3.1 Logistics solutions facilitating reusable packaging system

Outcome 3.2 Costs and value determinants of logistics for reusable packaging system

Outcome 3.3 Economically feasible logistics solutions for reusable packaging system

Logistics modelling: grocery home delivery use case

Key takeaways from logistics modelling of grocery home delivery use case

- After 20 cycles, the reusable online grocery pick-up packaging becomes cheaper
- Could be either used by one store or between several stores or even chains, to streamline washing solutions

Reusable grocery home delivery packaging process in comparison to single-use

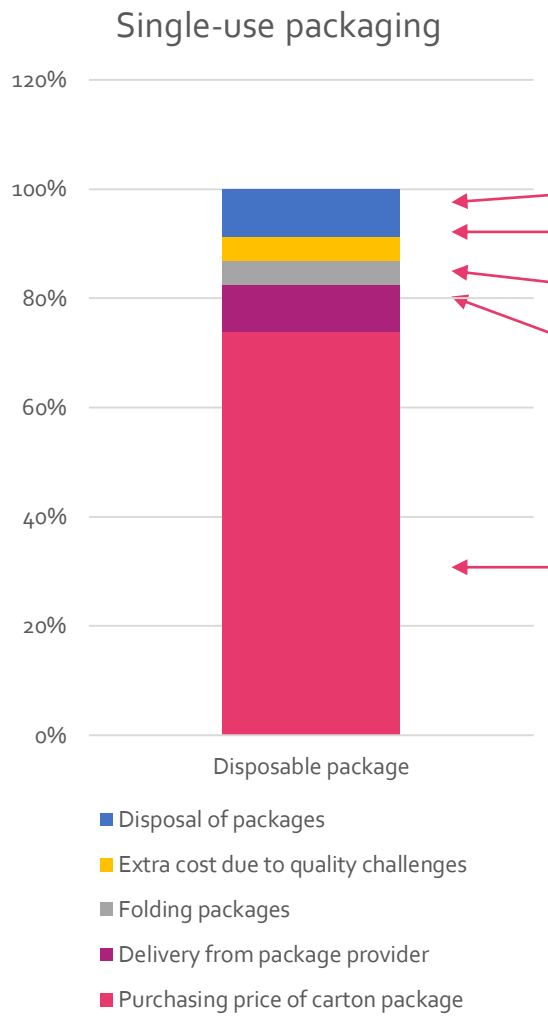






	Receiving at store	At store (staff area)	At store (public area)	Dispatching area	Customer delivery	At home	Disposal / returning
Single-use (current system)	• Delivery of packaging	• Receiving, shelving, storing and folding packaging	• Collection of orders	• Storing collected orders • Loading delivery vans • Order pick-up	• Delivering orders to customers	• Receiving orders	• Disposal of packaging
Reusable packaging (changes from single-use)	• Packaging returned from customers • Deposit returned to customer • Quality check	• Folding packaging can be faster • Storing requires more space • Washing	• No change to the current	• No change to the current	• Customer pays deposit	• Durability • Improved handling safety • Less harm from moisture	• Packaging returned to store
Added value for logistics from tracking the individual packaging	• Automated deposit accounting	• No added value	• Less human errors	• Faster loading • Less human errors	• Less human errors	• No added value	• No added value

Comparison of added costs of single-use and reusable online grocery pick-up packaging



After use

Consumer delivery

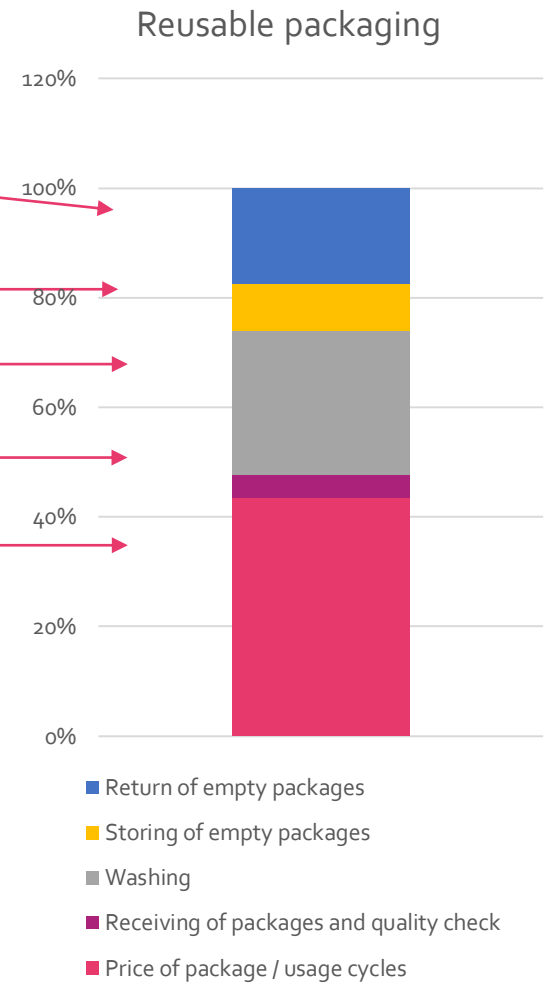
Start of collection

Receiving packages

Price of package

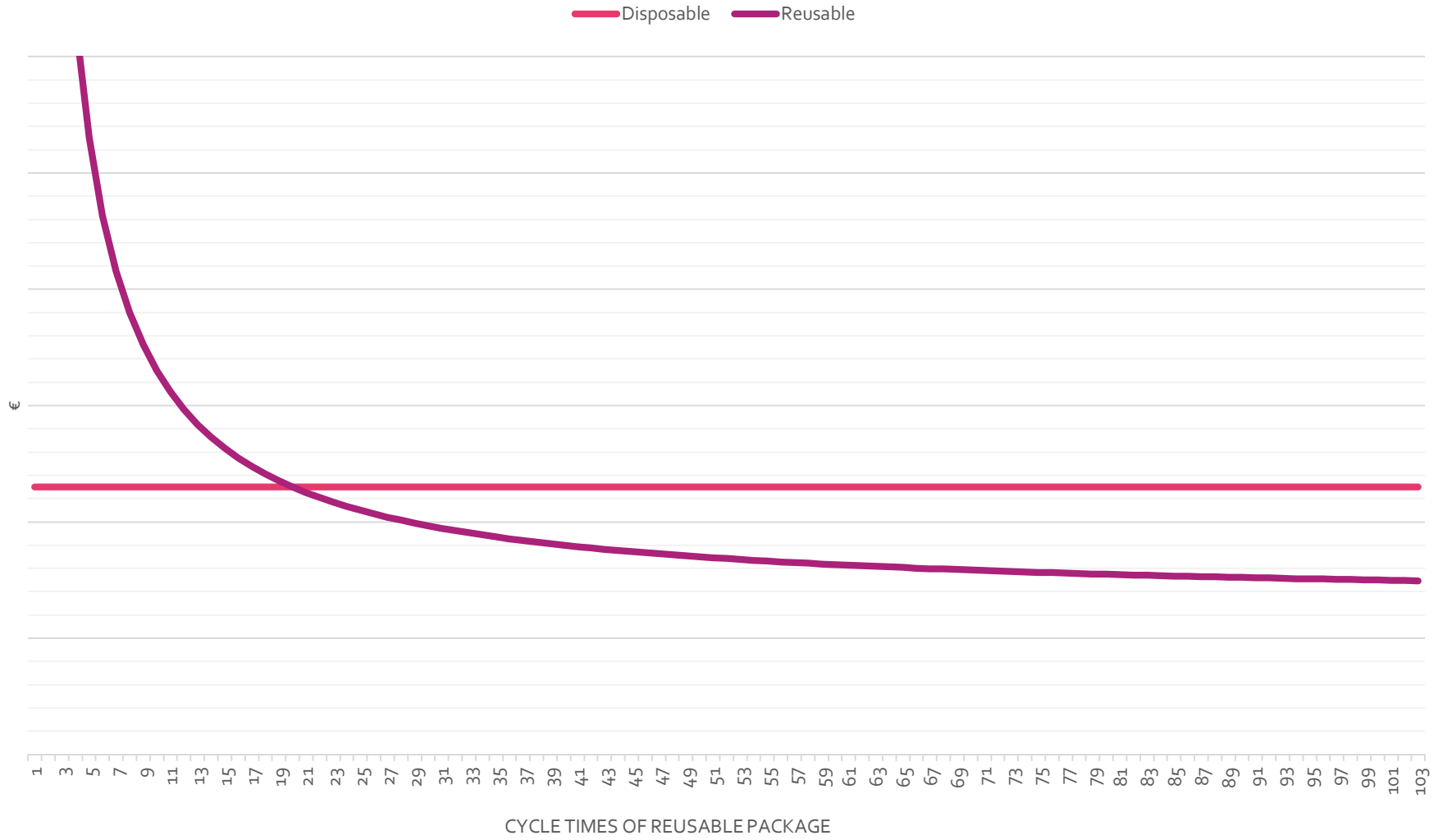
Storing

Washing



- The cost structure of single-use packaging is rather well-known
- However, there are many uncertainties related to cost structure of reusable packaging
- The right column is an example of the cost structure that enables equal costs of both alternatives

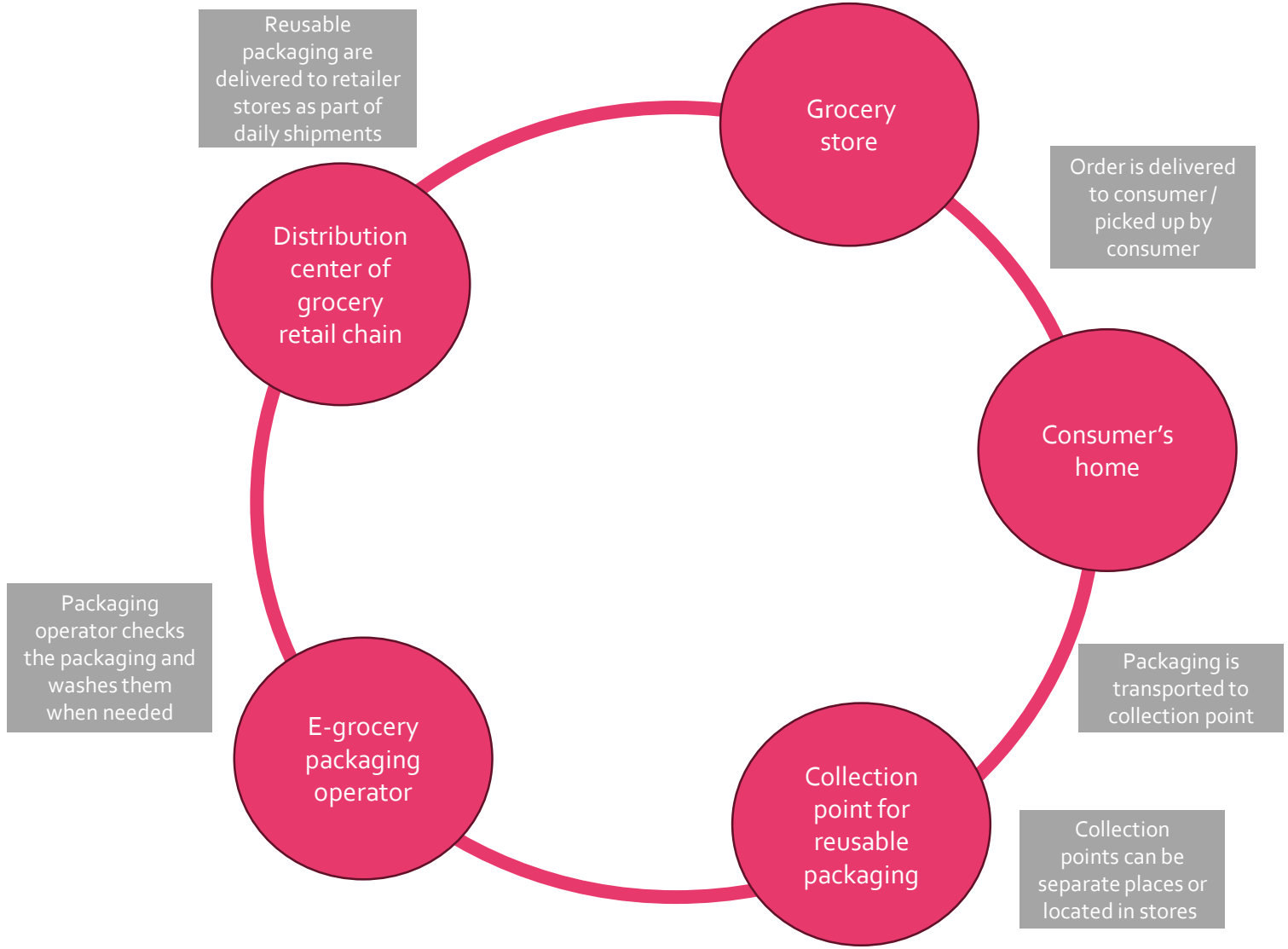
Cost comparison of single-use and reusable packaging by using the same values as on the previous page



- The break even point of comparison between single-use and reusable packaging in this case is 20 cycles
- After 20 cycles, the reusable online grocery pick-up packaging becomes cheaper

Concept proposition for organizing reusable grocery home delivery packaging between retail stores or chains

- The proposed concept would be used by many grocery retail stores and preferably between many grocery retail chains as a shared asset
- A separate packaging operator is responsible for organizing transportation from collection points to distribution center and washes the packaging when needed
- Grocery stores would get the empty boxes as part of daily shipments from the distribution center



Logistics modelling: hospital food delivery system use case

Key takeaways from logistics modelling of hospital use case

- The most cost effective solution is scenario 3: outsourcing with high level of washing automation and shorter transport

Hospital food delivery process with reusable packaging

Done by the hospital personnel

Done by the service provider

4everPack

Central kitchen packs food

START/END OF CYCLE

Packages are gathered to trolleys

Packages are delivered to hospital departments

Heating

Food delivered to patients

Used packages are collected & stacked

Used package pickup & transportation

Packages are washed & inspected

Packages are bundled ready to be redistributed

Packages are delivered back to the central kitchen

Metos Burlodge Trolley

Conveyor dishwashing machine

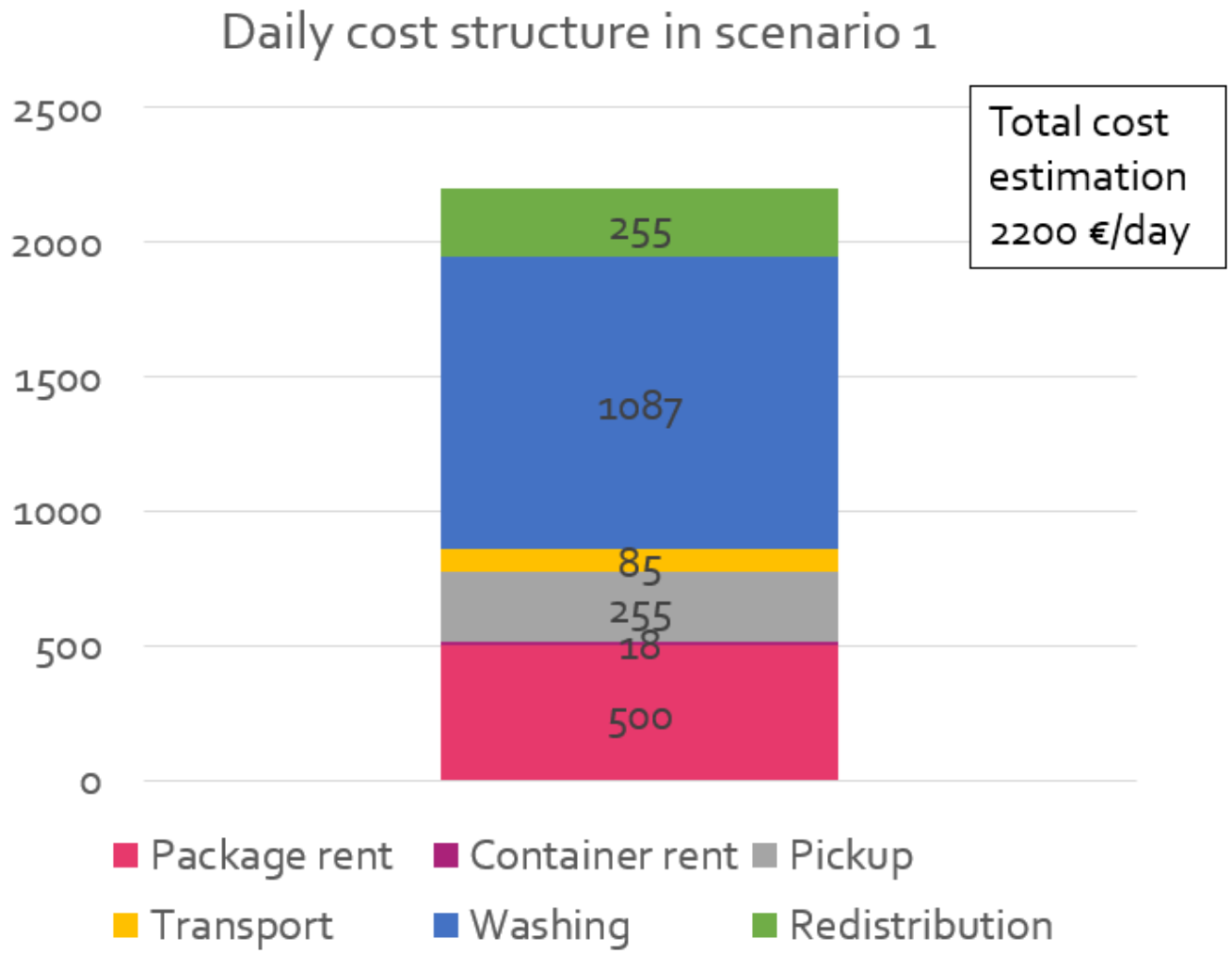
VOLUME

- 9000 meals per day
- Weekend meals are prepared beforehand (4 days)

-> Maximum package need incl. spare: 50 000 (4+1 days)

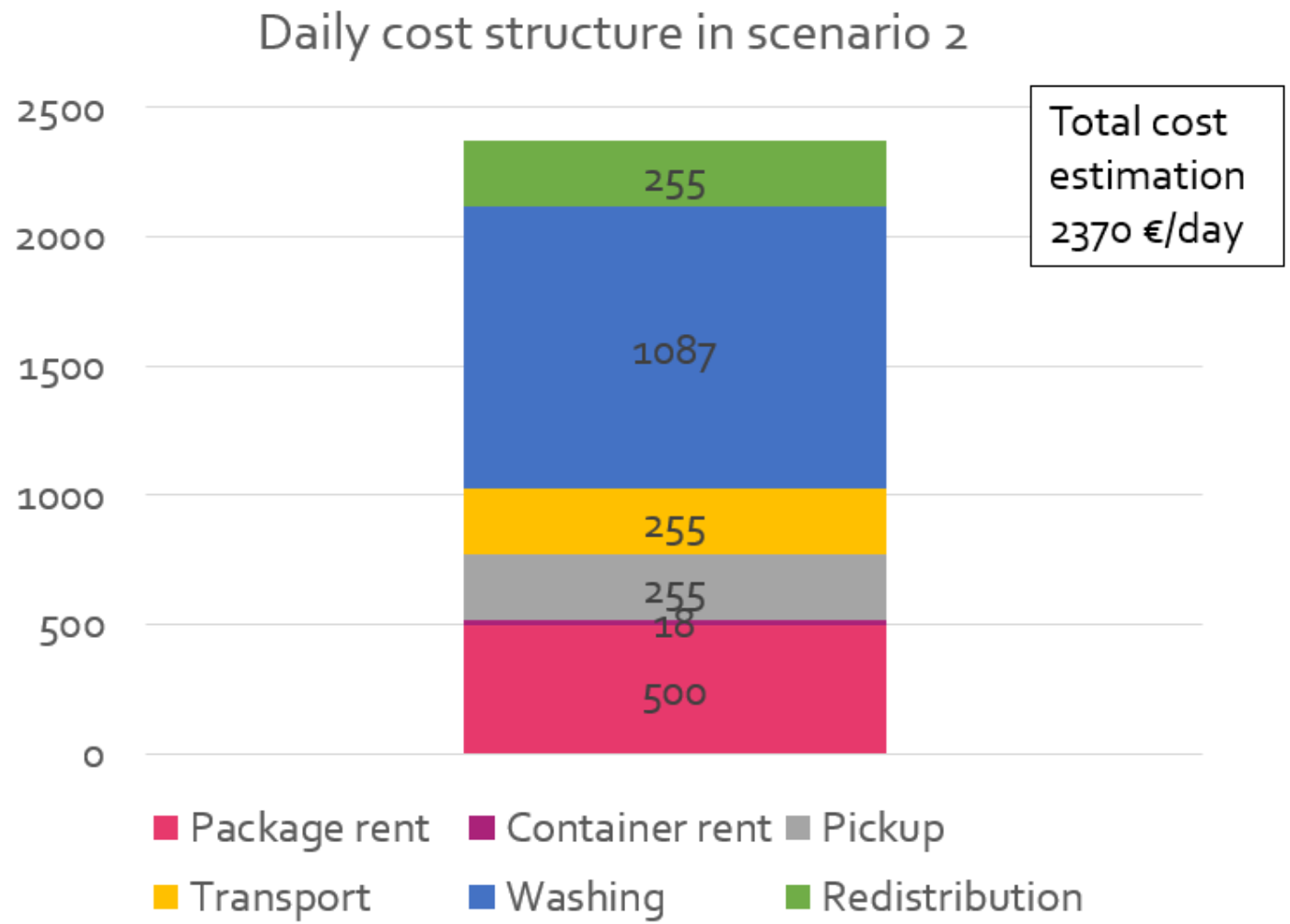
Food package delivery system, scenario 1: Outsourcing with low level of washing automation and shorter transport

Source information	
Labour costs, Pickup / redistribution	35 €/h
Vehicle cost (truck without a driver)	50 €/h
Working hours, Pickup / redistribution	6 h/day
Washing (machine, detergent, etc.)	0,2 €/wash
Labour costs, washing	25 e/h
Working hours, washing (5 employees)	35 h /d
Vehicle cost (truck with a driver)	85 €/h
Driving time (1 km in the hospital area)	0,25 h
Legs per day	4
Container rent	0,10 €/d/piece
Amount of containers	72 pcs
Food package rent	0,01 €/d/piece
Amount of food packages	50 000 pcs



Food package delivery system, scenario 2: Outsourcing with low level of washing automation and longer transport

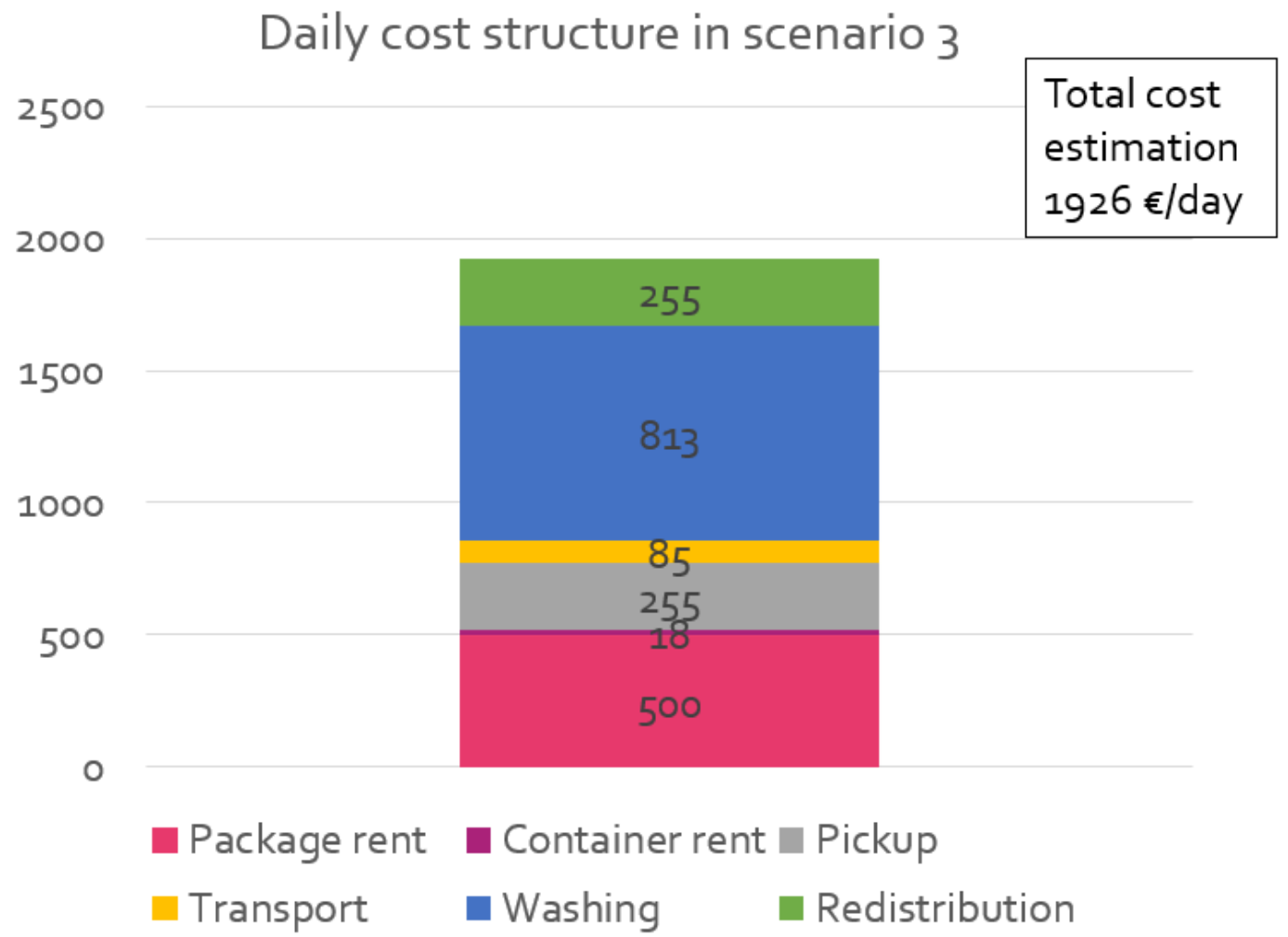
Source information	
Labour costs, Pickup / redistribution	35 €/h
Vehicle cost (truck without a driver)	50 €/h
Working hours, Pickup / redistribution	6 h/day
Washing (machine, detergent, etc.)	**0,2 €/wash**
Labour costs, washing	25 e/h
Working hours, washing (5 employees)	**35 h /d**
Vehicle cost (truck with a driver)	85 €/h
→ Driving time (Driving time: 1 km in the hospital area + 15 km to the washing facility)	**0,75 h**
Legs per day	4
Container rent	0,10 €/d/piece
Amount of containers	72 pcs
Food package rent	0,01 €/d/piece
Amount of food packages	50 000 pcs



Changes compared to scenario 1 marked with arrow symbol

Food package delivery system, scenario 3: Outsourcing with high level of washing automation and shorter transport

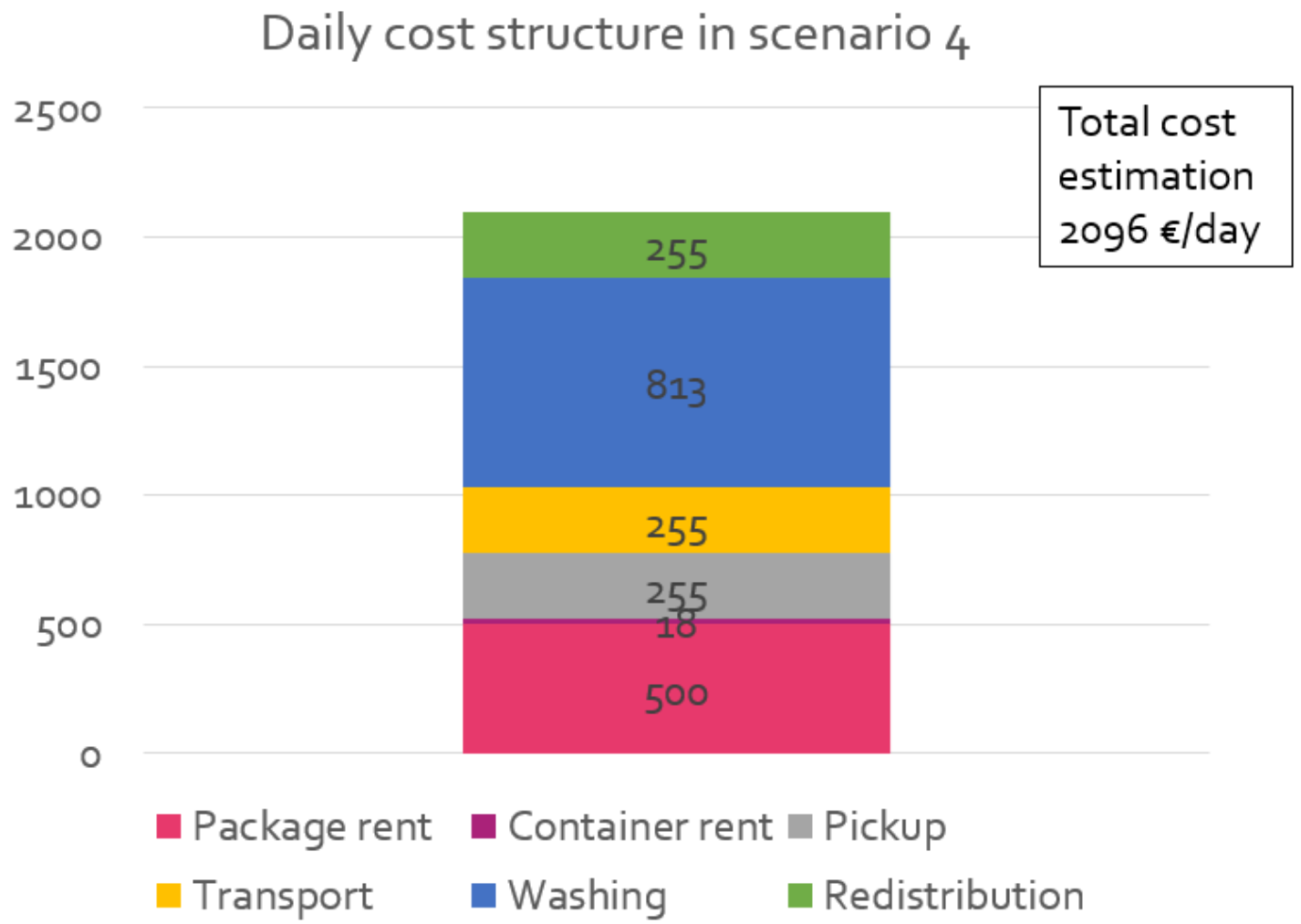
Source information	
Labour costs, Pickup / redistribution	35 €/h
Vehicle cost (truck without a driver)	50 €/h
Working hours, Pickup / redistribution	6 h/day
→ Washing (machine, detergent, etc.)	**0,5 €/wash**
Labour costs, washing	25 e/h
→ Working hours, washing 2 employees)	**15 h /d**
Vehicle cost (truck with a driver)	85 €/h
Driving time (1 km in the hospital area)	**0,25 h**
Legs per day	4
Container rent	0,10 €/d/piece
Amount of containers	72 pcs
Food package rent	0,01 €/d/piece
Amount of food packages	50 000 pcs



Changes compared to scenario 1 marked with arrow symbol

Food package delivery system, scenario 4: Outsourcing with high level of washing automation and longer transport

Source information	
Labour costs, Pickup / redistribution	35 €/h
Vehicle cost (truck without a driver)	50 e/h
Working hours, Pickup / redistribution	6 h/day
→ Washing (machine, detergent, etc.)	**0,5 €/wash**
Labour costs, washing	25 e/h
→ Working hours, washing 2 employees)	**15 h /d**
Vehicle cost (truck with a driver)	85 €/h
→ Driving time (1 km in the hospital area)	**0,75 h**
Legs per day	4
Container rent	0,10 €/d/piece
Amount of containers	72 pcs
Food package rent	0,01 €/d/piece
Amount of food packages	50 000 pcs



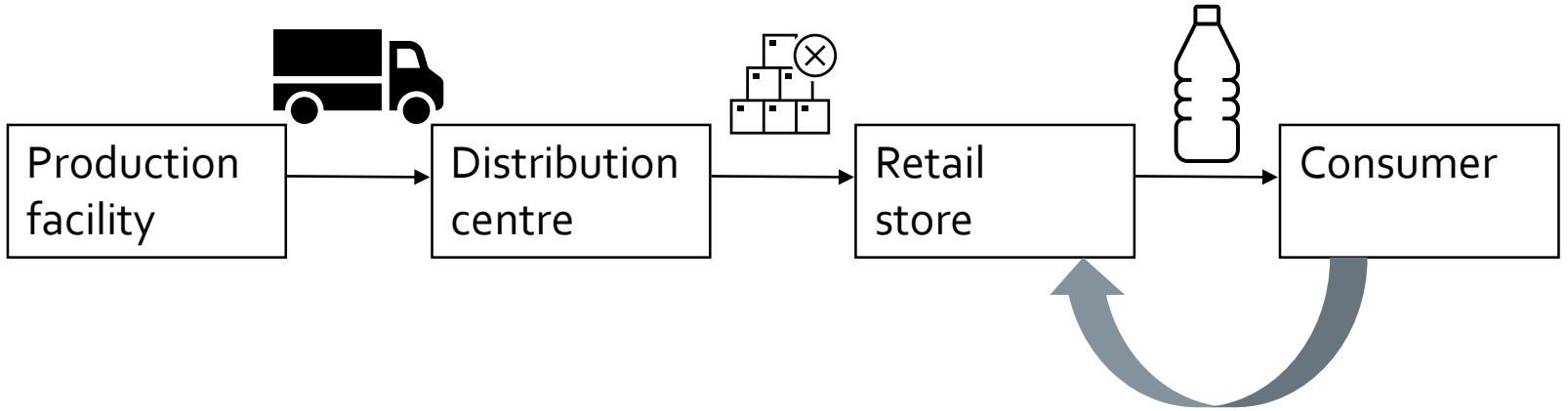
Changes compared to scenario 1 marked with arrow symbol

Logistics modelling: detergent use case

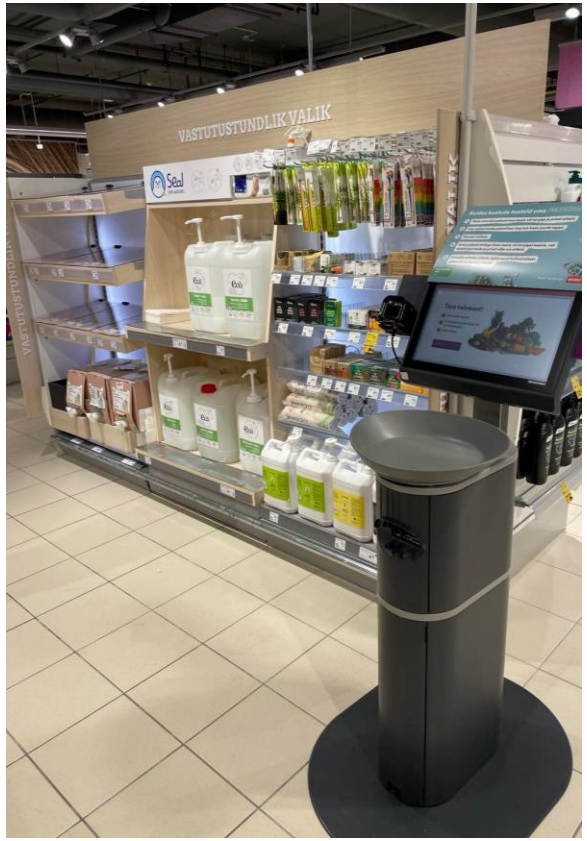
Key takeaways from logistics modelling of detergent use case

- Three alternatives were identified from one actor implementation to supply chain implementation

Supply chain of detergent bottles: Alternative 1: Consumer uses same packaging for refill

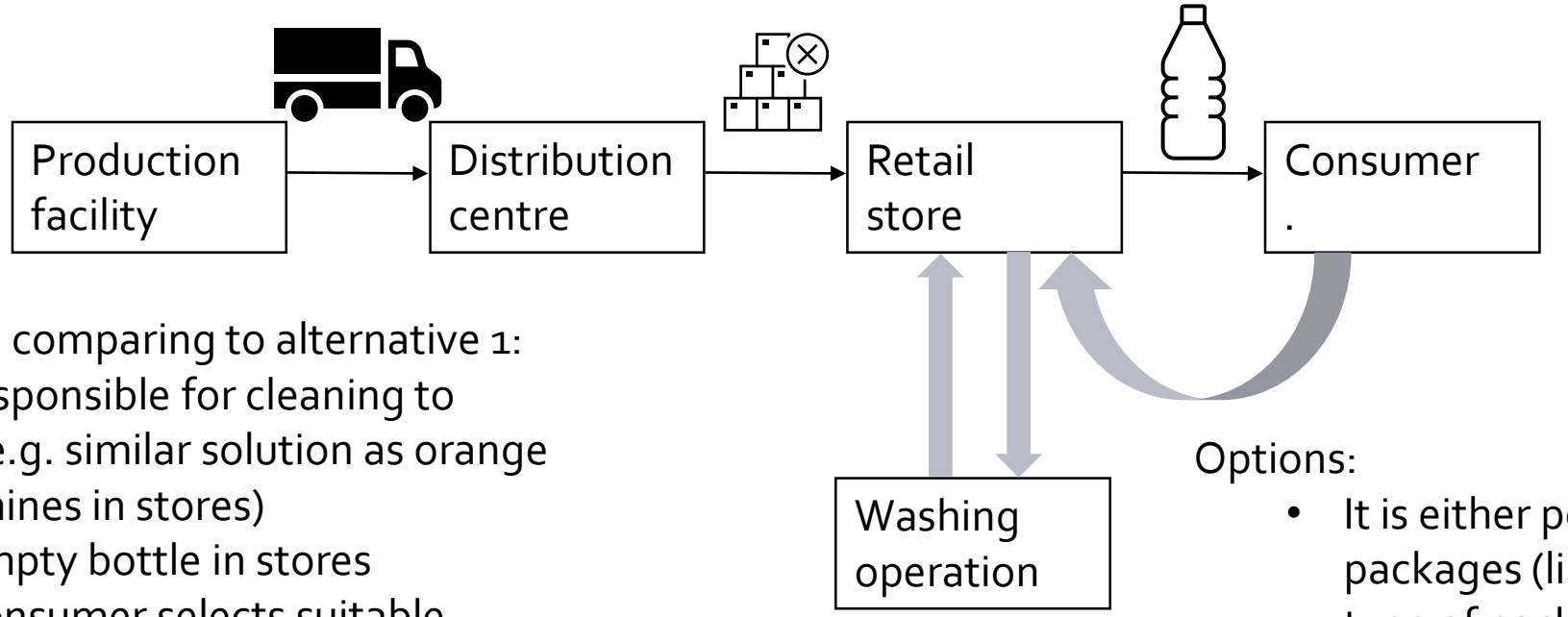


- Used e.g. in Estonia in grocery store and in some small stores in Finland
- Benefits:
  - Relatively easy to implement
  - Also wholesale packages can be reused
- Challenges:
  - Responsibility for suitability (e.g. if the bottle has traces of some material which may theoretically create dangerous compound with the detergent)
  - May be difficult for store personnel to control possible consumer errors



Picture: Anna Tenhunen-Lunkka

Supply chain of detergent bottles: Alternative 2: Store offers empty bottle for refill



Difference comparing to alternative 1: Store is responsible for cleaning to package (e.g. similar solution as orange juice machines in stores)

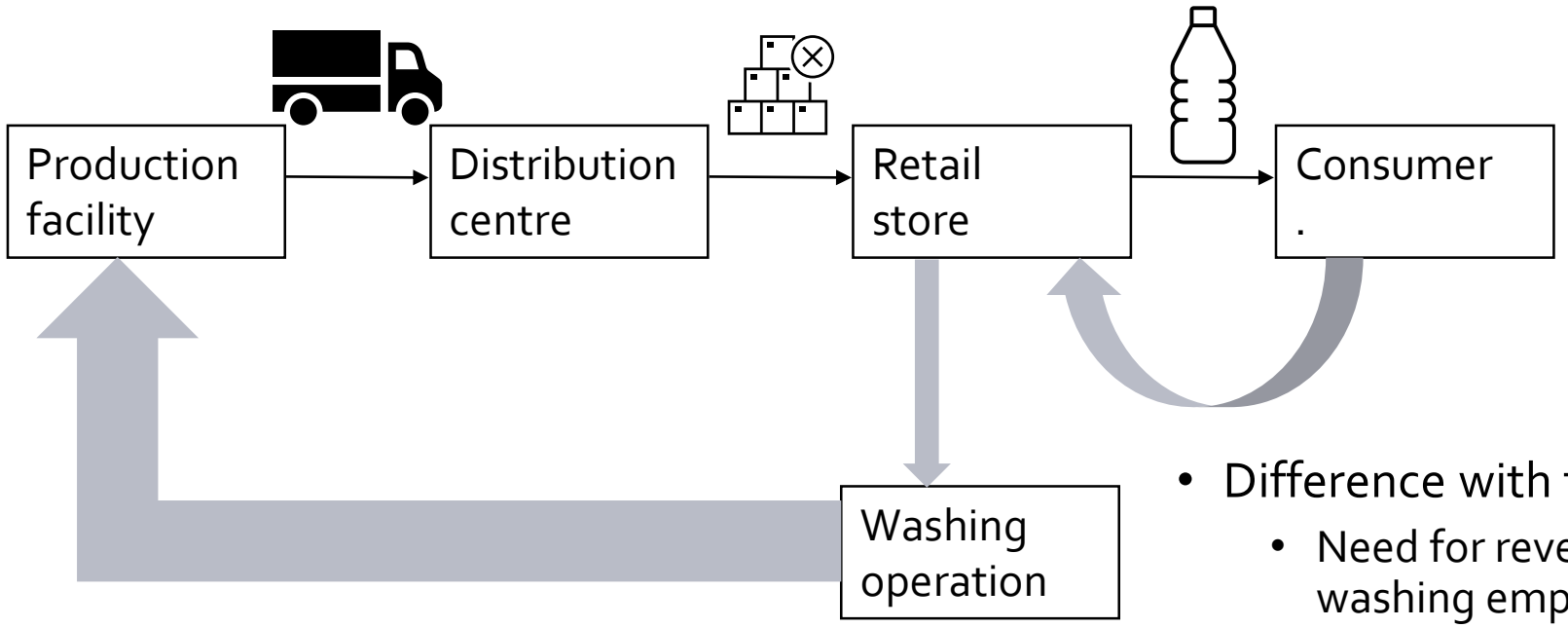
- Empty bottle in stores
- Consumer selects suitable package or prints a label to blank bottle
- Consumer returns empty package to store (and may get deposit back)

Picture: Ville Hinkka

Options:

- It is either possible to use wholesale packages (like in Alternative 1) or other type of packages suitable for filling machines (like coffee machine)
- Reusable bottles may be different for each product or they are blank (and consumer prints a label and product info in that case)

Supply chain of detergent bottles: Alternative 3: Producer refills reusable bottles



- Difference with the current solution:
  - Need for reverse logistics solutions and washing empty bottles
- Challenges:
  - Efficient management of reverse logistics costs to avoid exceeding the costs of material recycling and producing new bottle

Key takeaways from WP3 – Logistics solutions for reusable packaging

- Identified supply chain alternatives for three different reusable packaging use cases
  - The needs are case specific especially depending on the product type
- Missing activities, such as collection and washing of the reusable packaging need to be organized either by new or existing actors
- The simplest closed-loop supply chain solutions for reusable packaging require more effort from the consumer but can be set up by one actor
- The more advanced reusable packaging reverse supply chain requires planning, infrastructure investments, collaboration between supply chain actors and critical volumes for economies of scale

Image source: unsplash.com

7: WP4 European consumer acceptance of reusable packaging

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Objectives and outcomes

Objectives

a) To generate an understanding of the main facilitators and barriers for reusable FMCG packaging system from European consumers' viewpoint.
b) To assess the attractiveness and feasibility of FMCG products offered in reused packages in European consumer markets.

Outcomes

Outcome 4.1 Facilitators and barriers for European consumer acceptance of FMCG reusable packaging system. The most feasible market segments identified

Outcome 4.2 Assessment of the attractiveness and feasibility of products offered in reused packages in European consumer markets

Overview of WP4 activities

- Exploration of European consumers' views on reusable packaging
  - Online community study (N=20 / country)
  - Online survey (N=800 / country)

- Validation of European consumers' interest in reusable packaging
  - Product choice experiment (N=300 / country)
  - Product trial experiment (N=100 / country)

- All studies were conducted in Finland, Germany & the UK

Image source: unsplash.com

Exploration results

- **Reusable packaging is a relatively new concept to European consumers**
- **It generates positive views and feelings and is spontaneously associated with environmental sustainability**
  - Occasionally, it is confused or compared with recycling, especially in countries where recycling is a common practice

- **Positive emotions drive European consumers' intentions to try, buy, and recommend products in reusable packaging**
  - Sense of control, beliefs that close others (e.g. family and friends) will approve and support reuse, and positive attitudes also drive intentions
  - Perceived functional (e.g. convenience), emotional (e.g. feeling good), and environmental (e.g. protection) values associated with reusable packaging influence consumers' attitudes

- **Price, convenience, and environmental impact influence consumers' expectations, concerns, and motivation to use products in reusable packaging**
  - Expected lower price as compared to "standard" packaging
  - Forseen "extra" effort and habitual changes (e.g. store, return packages) form consumers' concerns over convenience
  - Consumers often associate reusable packaging with positive environmental impact but for some, such idea is met with skepticism


Image source: unsplash.com

Validation results

- **Products in reused plastic packaging were chosen more often than the ones in single-use plastic packaging**
  - Reused packaging performed especially well in home cleaning products
  - Within food, personal care and home cleaning categories, product type did not exert influence on product packaging choices
  - Reused packaging evoked higher taste & effectiveness expectations and positive feelings in comparison to single-use (and in some cases recyclable) packaging

- **Product category has a significant role in consumers' experiences with products in reused plastic packaging**
  - Consumers' evaluations for reused (vs. single-use) packaging were significantly more positive for the personal care product category
  - No significant differences in evaluations were observed in the food category

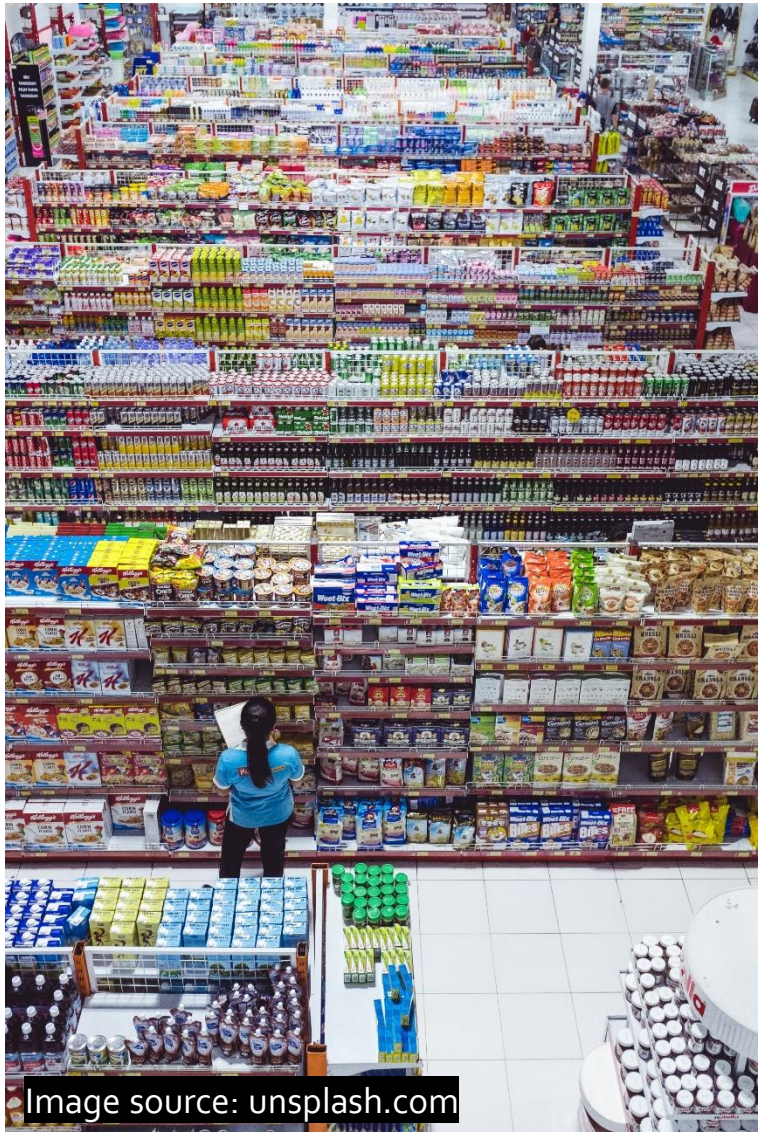

Image source: unsplash.com

WP4 - Key take-aways

- **European consumers** hold **positive views, attitudes** and **intentions** toward reusable packaging
- Consumers **inherently associate** reusable packaging with **environmental sustainability**
- Environmental value **is not the main driver** of consumers' attitudes and intentions
  - **Affective factors** (emotional value and emotions) **predicted** attitudes and intentions and **resulted** from hypothetical choices and concrete product use (taste/use-induced emotions, warm glow)
- Reusable packaging can produce **intangible value** to consumers
  - Marketing highlighting emotional and social meanings of reuse in connection with env. sustainability might work as key marketing argument
- Future areas of research
  - How to **balance** the costs of packaging reuse (time, convenience) and intangible benefits to tip the scale?
  - How to concretize this intangible value proposition?

Image source: unsplash.com

8. WP5 Circular business models and roadmap to export markets

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WP5 overview
Circular business models

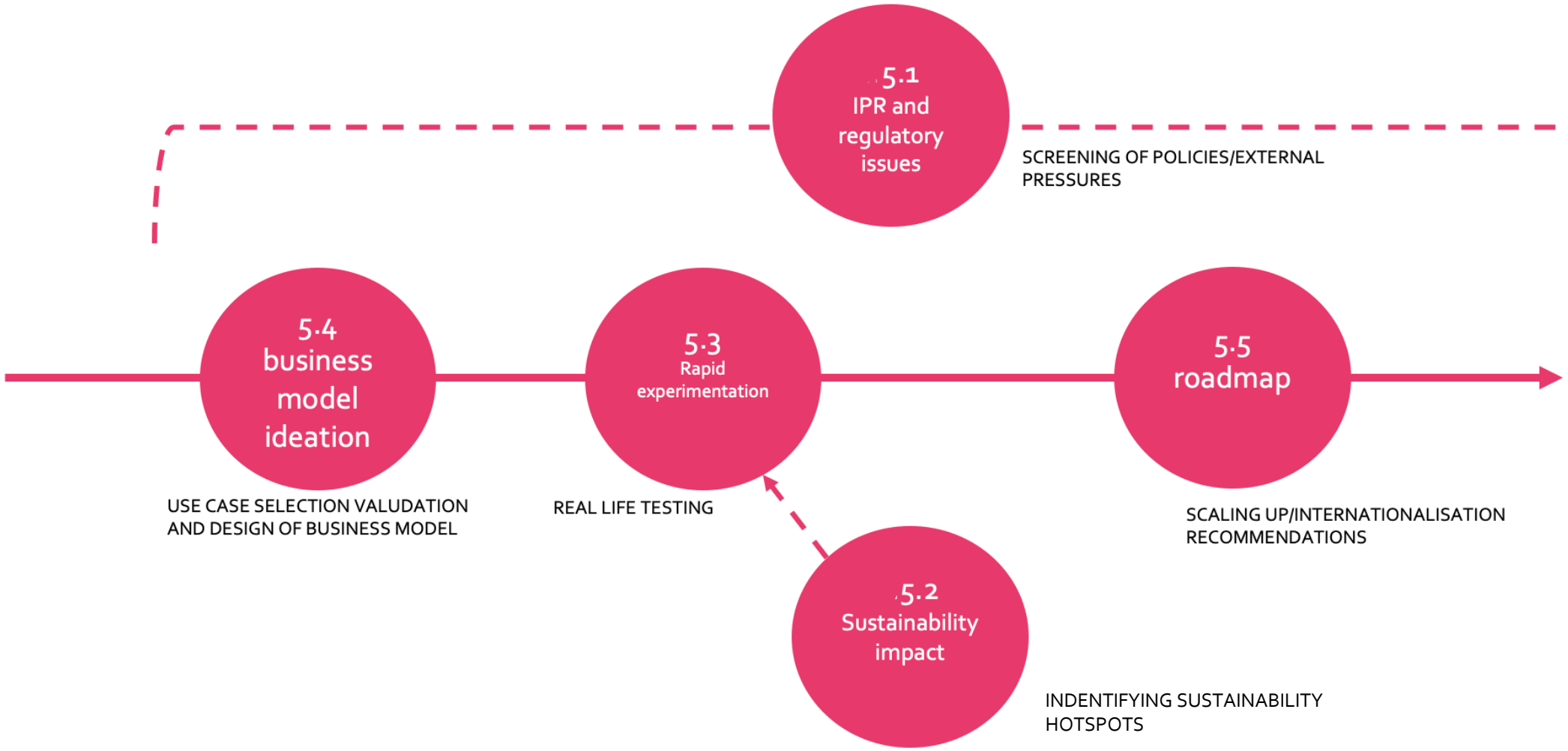
Objectives:

a) Understand the **value creation** and sharing **models** in novel reusable packaging ecosystem
b) **Innovate and pilot** new sustainable business models in reusable packing ecosystems
c) Develop **paths** to export reusable packaging system to international markets.

Outcomes:

Outcome 5.1 A framework of IPR, regulatory and R&D landscape for reusable packaging
Outcome 5.2 The key sustainability elements of reusable packaging system
Outcome 5.3 Circular business models for reusable packaging
Outcome 5.4 Roadmap to export markets to support sustainable business growth for Finnish companies

WP5 task overview



T5.1 Regulatory issues

Policy landscape on packaging reuse

- During the past years increasing policy interest in the EU related to **packaging waste prevention**
- Waste hierarchy principle has been a guiding principle in EU's waste policies (e.g., Waste Framework Directive WFD)
- However, despite of policy goals and measures the amount of **packaging waste has been increasing and is projected to increase in the future**

Source: EC

Policy landscape on packaging reuse

- New targets and measures has been set to overcome the waste problem
  - Reuse is seen as a way reduce waste generation and littering
- **The European Green Deal** (2019)
  - All packaging in the EU market is reusable or recyclable in an economically viable manner by 2030
- **Single-use Plastics Directive** (2019)
  - Bans and consumption reduction obligations on certain single use plastic products
  - The directive gives priority to sustainable and non-toxic reusable products and reuse systems, including reusable packaging
  - No quantitative reuse targets yet

Policy landscape on packaging reuse

- **Proposal for Packaging and Packaging Waste Regulation** (2022, forthcoming)
  - 5 % reduction of waste generation by 2030 compared to 2018
  - Bans, e.g.,
    - On using single-use packaging for food and beverages filled and consumed within the premises in the HORECA sector
  - Sector specific reuse targets for packaging, e.g.,
    - Takeaway ready prepared food: 10% (2030) and 40% (2040)
    - Hot and cold beverages: 20% (2030) and 80% (2040)
  - Support the establishment of efficient reuse and refill systems
  - Harmonised labelling, including labelling for reuse

Key takeaways and recommendations

INCREASING POLICY PRESSURE	• There is an increasing EU policy pressure to reduce single-use packaging consumption and increase packaging reuse and development of such systems
FEAR OF FALLING BEHIND – MORE INCENTIVES NEEDED	• Current EU and Finnish policy mixes set a good starting point for a systemic change, but to ensure that Finland does not fall behind from other member states further policy incentives, such as innovation policies and more stringent legislation, are needed to accelerate the transformation
NEW INSTRUMENTS NEED TO BE ALIGNED WITH EXISTING ONES	• However, the new policy instrument need to be aligned with the existing policy mix, which entails e.g. food contact materials, REACH, hygiene, and packaging and packaging waste laws and regulations, producer responsibility

To learn more…

https://publications.vtt.fi/pdf/technology/2023/T415.pdf

T5.2 Environmental sustainability

Environmental sustainability of reusable packages during their life cycle

Life cycle phase of reusable plastic package	Things to consider from the environmental sustainability point of view
Design	Are the packages fit for purpose but with as little amount of plastic/raw materials as possible and as light as possible?
Production of the plastic material and manufacturing of the packages	Is the machinery up to date, the energy and water consumption optimized, the renewable energy sources prioritized, and waste formation minimized?
Use, refill and reuse	Are the customers motivated to use the reusable or refillable packages and do they know how to use, reuse and refill them?
Collection/ take back	Is the collection easy enough for the customers? Is the distance to the collection point and the amount of collection points reasonable for the customers?
Logistics and distribution	Is the way to transport (ship, plain, truck, etc.) and the fuel choice the best options considering the weight, shape and size of the package and the driving distance? Are the routes and drives optimized?
Washing and reconditioning	Are the energy and water usage and the consumption of the disinfectant minimized?
End of life management	Are the packages reused many times enough before the end of life? What is the chosen waste management strategy (recycling, incineration, landfilling)?

Top three factors affecting the environmental sustainability of reusable packages

Washing (and reconditioning) of the packages

- The environmental impacts turn out to be mostly influenced by heating of the water since especially in the case of food package, the washing temperature should be high due to the hygienic issues
- The washing times and used chemicals also cause some of the environmental effects
- According to the interviews, washing can cause up to 50 % of the environmental load of the reusable food packages

Raw material production

- The raw material of the packages is plastic so as a fossil based raw material, its' production causes lot of environmental load

Logistics

- The weight of the package was seen to have the biggest effect on the environmental burden
- The environmental effects of logistics also depend on the fuel used, the driving distances and the volume of the drives

Key take aways and recommendations

Low-hanging fruits

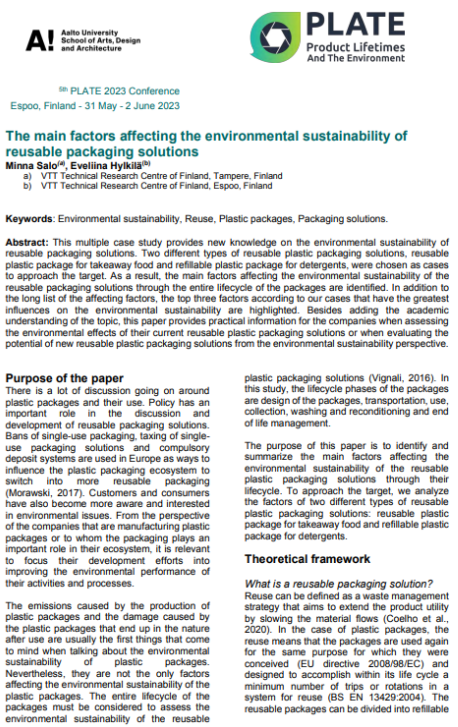
- Light-weighting the packages
- Removing unnecessary use of packaging
- Increasing the usage of recycled content in less sensitive applications (for instance non-food packages)
- Using more mono-materials
- Communicating the sustainability of the products for the customers better

Harder but doable

- Networking and cooperating with other players
  - What partnerships would be needed to innovate "game-changing" packaging solutions that are truly designed for sustainability

System-level changes

- Putting efforts to improve coordination across the value chain
  - Improve existing recycling infrastructure, recycling technologies, and circular value chains
  - New initiatives to increase consumer awareness or developing new types of materials



Aalto University School of Arts, Design and Architecture

PLATE Product Lifetimes And The Environment

5th PLATE 2023 Conference
Espoo, Finland - 31 May - 2 June 2023

The main factors affecting the environmental sustainability of reusable packaging solutions

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Keywords: Environmental sustainability, Reuse, Plastic packages, Packaging solutions.

Abstract: This multiple case study provides new knowledge on the environmental sustainability of reusable packaging solutions. Two different types of reusable plastic packaging solutions, reusable plastic package for takeaway food and refillable plastic package for detergents, were chosen as cases to approach the target. As a result, the main factors affecting the environmental sustainability of the reusable packaging solutions through the entire lifecycle of the packages are identified. In addition to the long list of the affecting factors, the top three factors according to our cases that have the greatest influences on the environmental sustainability are highlighted. Besides adding the academic understanding of the topic, this paper provides practical information for the companies when assessing the environmental effects of their current reusable plastic packaging solutions or when evaluating the potential of new reusable plastic packaging solutions from the environmental sustainability perspective.

Purpose of the paper

There is a lot of discussion going on around plastic packages and their use. Policy has an important role in the discussion and development of reusable packaging solutions. Bans of single-use packaging, taxing of single-use packaging solutions and compulsory deposit systems are used in Europe as ways to influence the plastic packaging ecosystem to switch into more reusable packaging (Morawski, 2017). Customers and consumers have also become more aware and interested in environmental issues. From the perspective of the companies that are manufacturing plastic packages or to whom the packaging plays an important role in their ecosystem, it is relevant to focus their development efforts into improving the environmental performance of their activities and processes.

The emissions caused by the production of plastic packages and the damage caused by the plastic packages that end up in the nature after use are usually the first things that come to mind when talking about the environmental sustainability of plastic packages. Nevertheless, they are not the only factors affecting the environmental sustainability of the plastic packages. The entire lifecycle of the packages must be considered to assess the environmental sustainability of the reusable plastic packaging solutions (Vignali, 2016). In this study, the lifecycle phases of the packages are design of the packages, transportation, use, collection, washing and reconditioning and end of life management.

The purpose of this paper is to identify and summarize the main factors affecting the environmental sustainability of the reusable plastic packaging solutions through their lifecycle. To approach the target, we analyze the factors of two different types of reusable plastic packaging solutions: reusable plastic package for takeaway food and refillable plastic package for detergents.

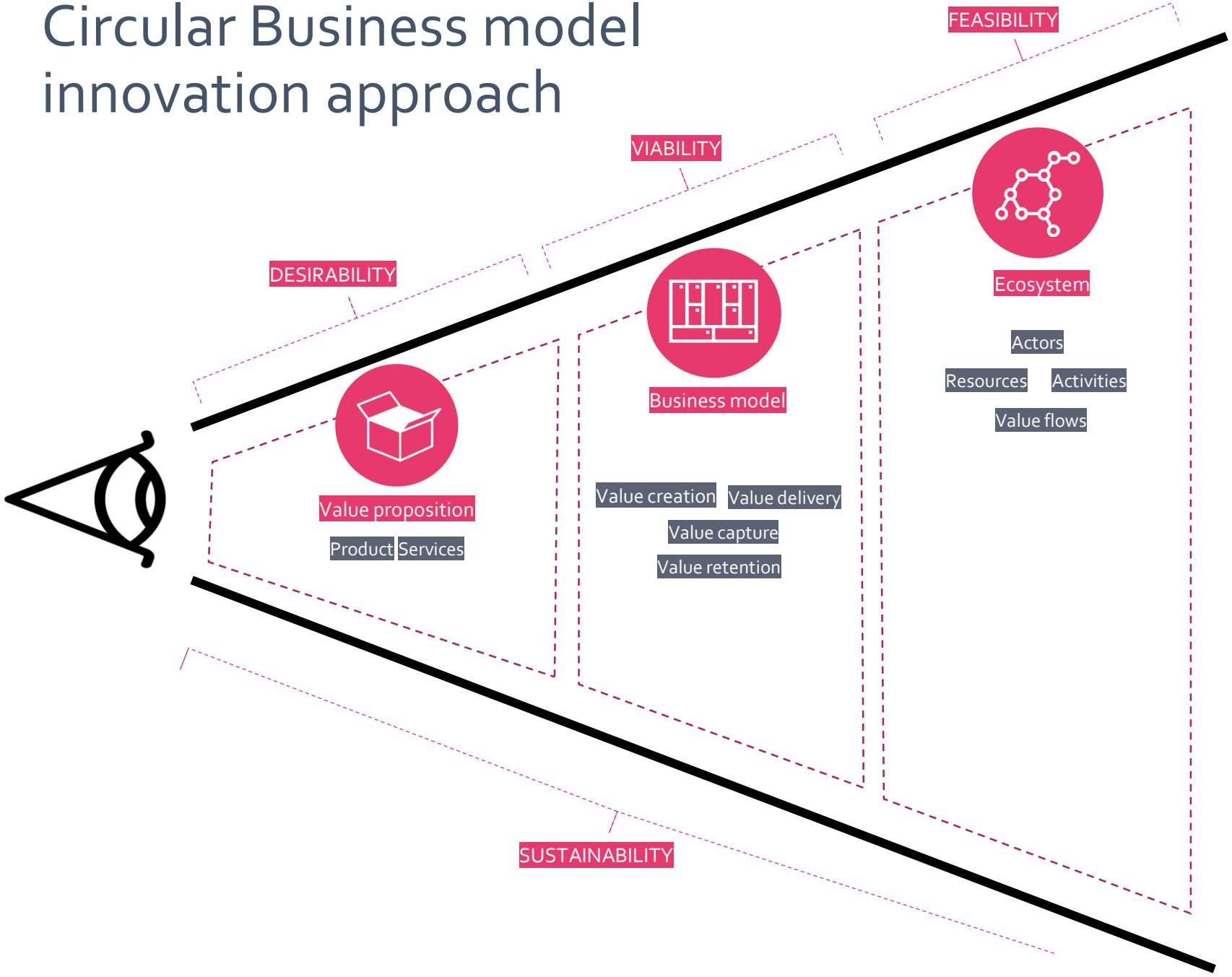
Theoretical framework

What is a reusable packaging solution?

Reuse can be defined as a waste management strategy that aims to extend the product utility by slowing the material flows (Coelho et al., 2020). In the case of plastic packages, the reuse means that the packages are used again for the same purpose for which they were conceived (EU directive 2008/98/EC) and designed to accomplish within its life cycle a minimum number of trips or rotations in a system for reuse (BS EN 13429:2004). The reusable packages can be divided into refillable

T5.3 Circular business model innovation

Circular Business model innovation approach



in 4everpack circular business model innovation is tackled through a system's perspective, zooming in to the core value proposition of reusable packaging, zooming out to the ecosystem elements that need to be put in place to enable an effective system. Ultimately we aim to design an implement business models that are desirable, feasible, viable and sustainable.

Business model innovation process

1. Ecosystem mapping	2. Service blueprint / user journey	3. Rapid experiments design	4. Cristallizing and Scale up
• stakeholders, roles, activities • benefits at actor level and ecosystem level • challenges/issues	• touchpoints • pain points	• Assumptions to validate for 4 value processes (creation, delivery, capture, circularity)	• learnings to update BMC, next steps

In the Business model innovation phase, each use case went through 3 sets of workshops organised between march and june 2022, leading to a cristallizing phase summarizing learnings.

15 multi-stakeholders workshops were organised in total.

A summary report sent to all stakeholders after every workshop.

Outcomes

At the end of this phase, the process allowed us to:

- get an overview of the ecosystem of each use case
- Identification of stakeholders role, resources, capabilities, expected benefits.
- Overview of processes and steps throughout the value chain
- Initial value proposition, painpoints and benefits expected
- Intial User journey focus

After all workshops, identification of main issues/challenges/uncertainties from a multiple lens perspective (materials, IT, logistics, business, sustainability, consumer acceptance)

> Input for the roadmaps of each Work Package

> Input for the framing of the experimentation phase.

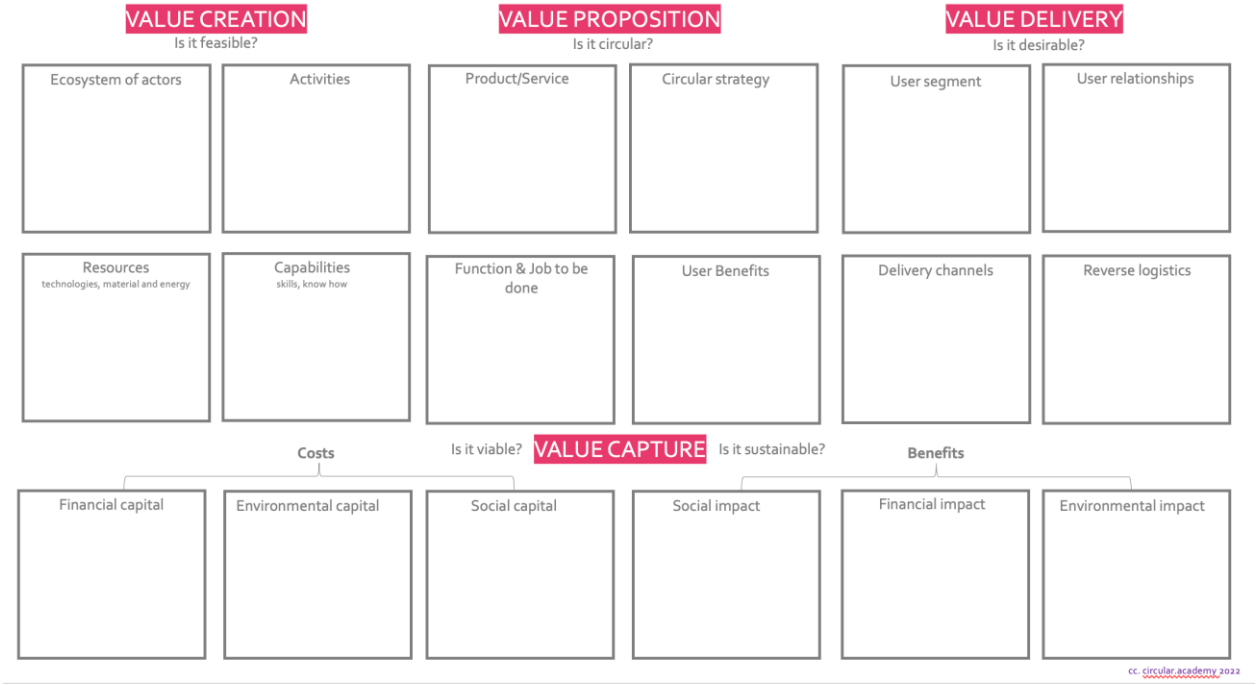
Screenshot from online business model innovation working board (miro)

To learn more…

The methodological approach and canvas are described in the following methodological guide available here

Key take aways

Business model innovation as a systematic approach to identify hotspots for successful transition towards reusable packaging systems (see next slide)



VALUE CREATION

Is it feasible?

Ecosystem of actors

key actors missing

Activities

key activities missing: logistics and washing

Resources

technologies, material and energy

packaging not designed for reusability

internal storage resources

Capabilities

skills, know how

ecosystem governance missing

VALUE PROPOSITION

Is it circular?

Product/Service

REUSABLE PACKAGING

Circular strategy

Function & Job to be done

similar features than single use: hygiene, protection of product + feeling good about doing somehting positive

User Benefits

functional value: convenience
price value: not more expensive
emotional value: warm glow
sustainability value

VALUE DELIVERY

Is it desirable?

User segment

go beyond the green-minded consumer

User relationships

communication on sustainability benefits + convenience and price and affective factors + Community feelling

Delivery channels

location to shift from single use to reusable on site – on the go - online

Reverse logistics

reverse model convenience for consumer

VALUE CAPTURE

Is it viable? Is it sustainable?

Costs

Financial capital

infrastructure and partnership costs: pooling

Environmental capital

holistic sustainability assessment based on data

Social capital

training of new skills and competences for staff

Benefits

Social impact

design for just transition > new technologies leave people behind

Financial impact

overall system more cost efficient. #number of cycles and return rate is key

Environmental impact

holistic sustainability assessment based on data

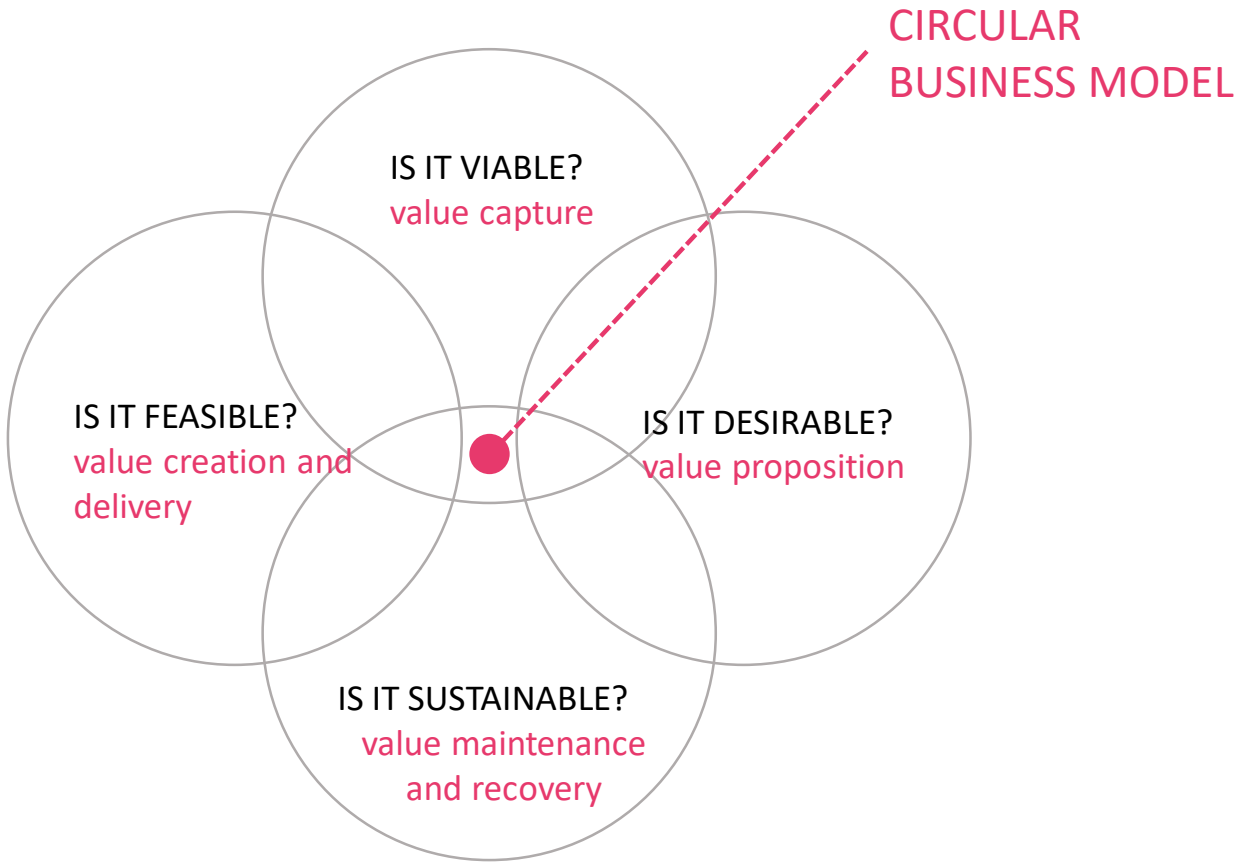
T5.4 Rapid experimentations

Why an experimentation approach?

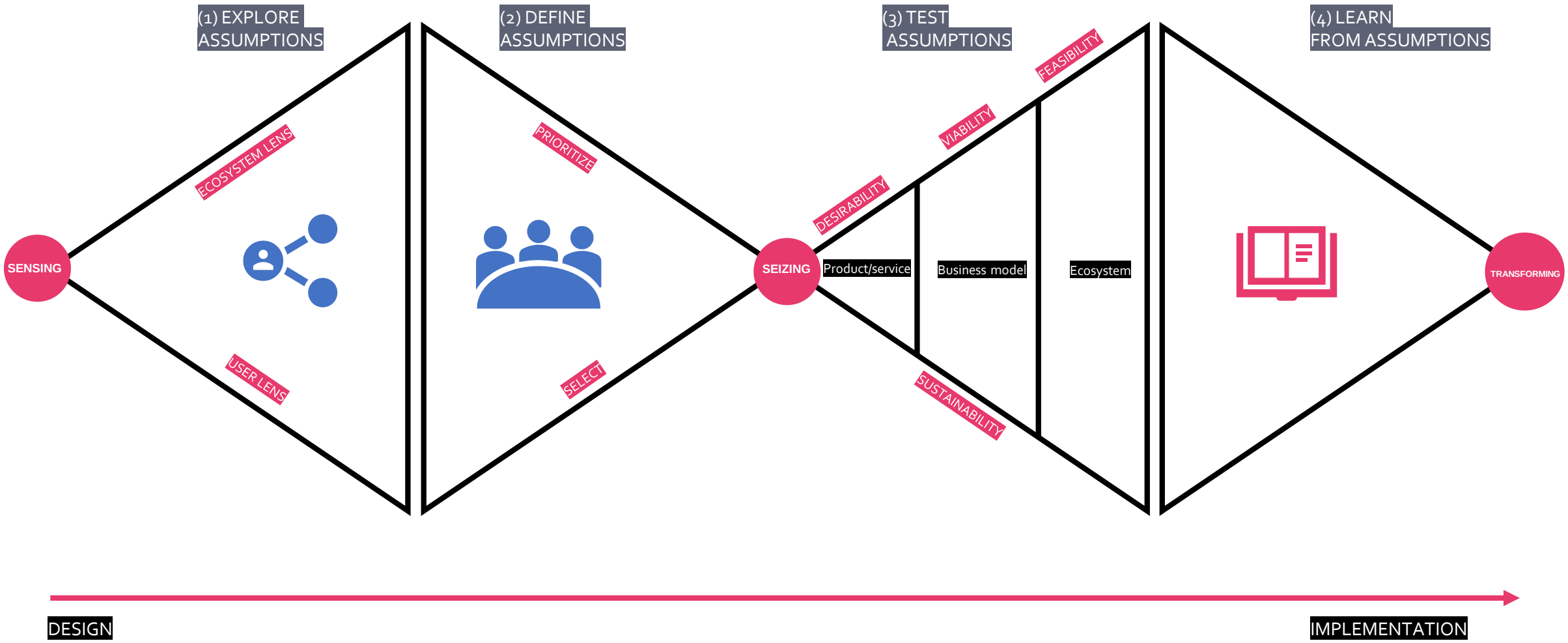
Rapid experimentation is a deliberate, purposeful, and conscious testing of activities, processes, and offerings in value creation, delivery, and capture. (Aagaard et al. 2021).

..through innovative, 'small-scale' experiments conducted in practice to address persistent societal problems (Van den Bosch, 2010)

...with a focus on deliberate learning by doing and **testing specific assumptions** at a time about the future business (Ries, 2011).



Rapid experimentation process

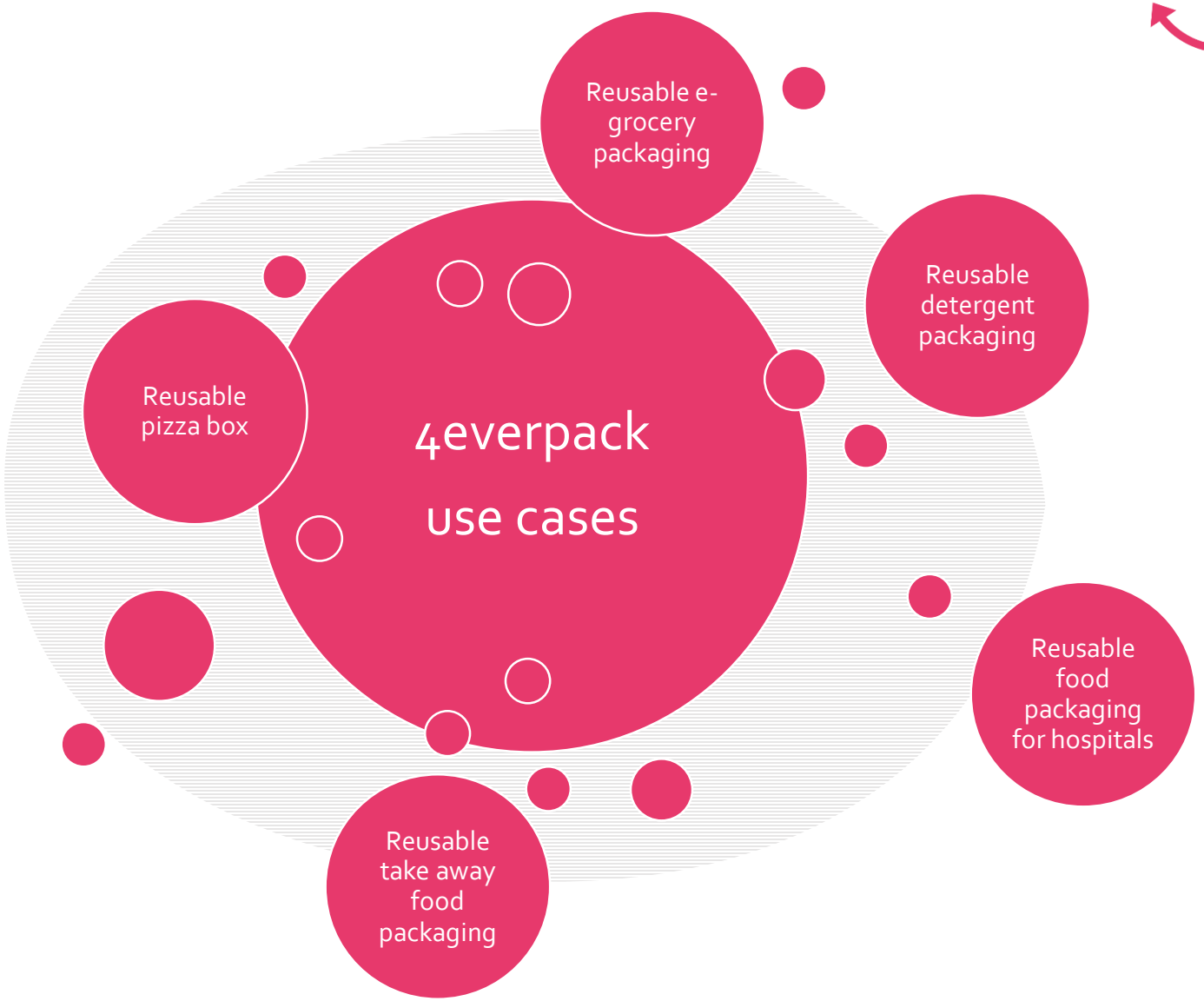


Rapid experimentation in 5 uses cases

Different level of ambition
based on starting point maturity

Different lenses: feasibility, desirability, viability, sustainability

Different methods:
brainstorming, desk research, pilots, surveys, etc…



Rapid experimentations overview

	Use case	Focus of experiment	Use case experiment
#1	Reusable food packaging for hospitals	Feasibility Feasibility	Test technical solution, ink for qr code for cold chain monitoring, map needs for tracking in the different stages of the value chain, logistics modelling Ecodesign workshop
#2	Reusable grocery home delivery package	Feasibility	Formulate generic concept for reusable scheme based on filed visit and brainstorming, define feature of packaging, highlight conditions for success, logistics modelling
#3	Reusable bottle packaging for detergents	Sustainability Desirability Feasibility	Sustainability analysis to define hotspots of the system. Experiment consumer perception with field test Ecodesign workshop, logistics modelling
#4	Reusable takeaway food packaging	Feasibility	Store location visit – test and experiment on labelling/stickers options Discussion with staff on feasibility
#5	Reusable pizza packaging	Desirability Feasibility	Consumer acceptance of the reusable pizza box through multiple pilots. Comprehension of staff and franchisees conditions for success Scratch test experiments

Key take aways

- Experimentation as **a bridge between prototyping and piloting**. It is necessary to validate assumptions of your business model.
- Experiment can identify new bottlenecks (i.e.: issue with package sticker, storage issues) at user, product or ecosystem level.
- Experiment can bring new insights from understudied stakeholders (i.e.: staff and franchisees feedback)

BUT

- Need to clarify the **ambition** of the experimentation and allocate right resources and competences (the more ambitious the more resources)
- Experimentation **capabilities** affect success. How to generate more know-how in your internal team?
- Experimentation **portfolio and timeline**: which experiment to begin with? How to organise experiments before reaching pilot level?
- Experimentation **process**: importance of clarifying success indicators Experimentation as a strategic decision-making tool. Go further or pivot.

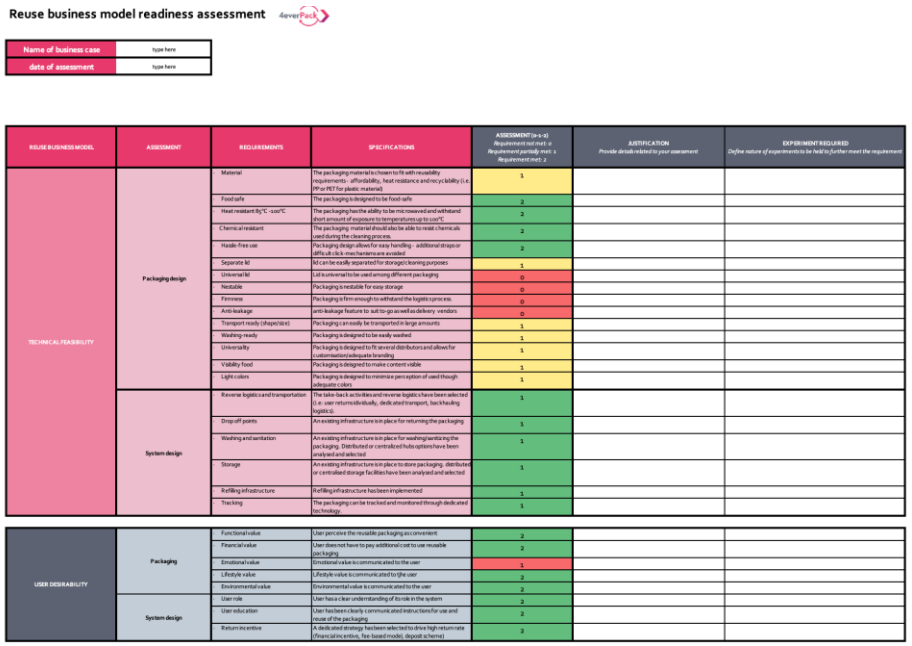
To learn more…

Reusable business model readiness assessment tool

A new tool to assess the level of advancement of a reuse business model

Helps to prioritize experiments needed to validate the business model

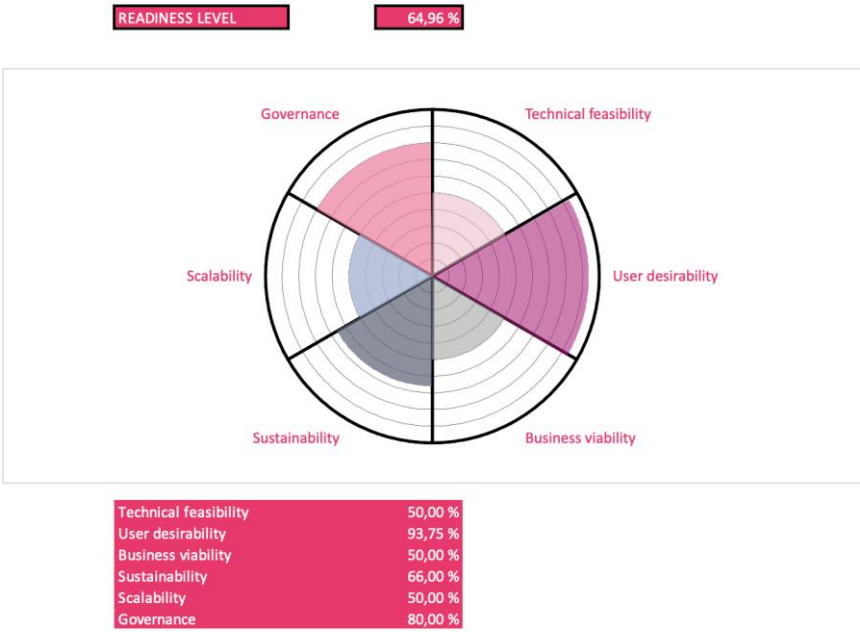
[Available here]



Reuse business model readiness assessment

Name of business case	type here
date of assessment	type here

REUSE BUSINESS MODEL	ASSESSMENT	REQUIREMENTS	SPECIFICATIONS	ASSESSMENT (0-1-2) Requirement not met: 0 Requirement partially met: 1 Requirement met: 2	JUSTIFICATION Provide details related to your assessment	EXPERIMENT REQUIRED Define nature of experiments to be held to further meet the requirement
TECHNICAL FEASIBILITY	Packaging design	Material	The packaging material is chosen to fit with reusability requirements - affordability, heat resistance and recyclability (i.e. PP or PET for plastic material)	1		
		Food safe	The packaging is designed to be food-safe	2		
		Heat resistant (by °C -100°C	The packaging has the ability to be microwaved and withstand short amount of exposure to temperatures up to 100°C	2		
		Chemical resistant	The packaging material should also be able to resist chemicals used during the cleaning process.	2		
		Hassle-free use	Packaging design allows for easy handling - additional straps or difficult click-mechanisms are avoided	2		
		Separate lid	lid can be easily separated for storage/cleaning purposes	1		
		Universal lid	Lid is universal to be used among different packaging	0		
		Nestable	Packaging is nestable for easy storage	0		
		Firmness	Packaging is firm enough to withstand the logistic process	0		
		Anti-leakage	anti-leakage feature to suit to-go as well as delivery vendors	0		
		Transport ready (shape/size)	Packaging can easily be transported in large amounts	1		
		Washing-ready	Packaging is designed to be easily washed	1		
		Universality	Packaging is designed to fit several distributors and allows for customisation/adequate branding	1		
		Viability food	Packaging is designed to make content visible	1		
		Light colors	Packaging is designed to minimise perception of used though adequate colors	1		
	System design	Reverse logistics and transportation	The take-back activities and reverse logistics have been selected (i.e.: user returns individually, dedicated transport, back hauling logistics)	1		
		Drop-off points	An existing infrastructure is in place for returning the packaging	1		
		Washing and sanitation	An existing infrastructure is in place for washing/sanitizing the packaging. Distributed or centralized hubs options have been analysed and selected	1		
		Storage	An existing infrastructure is in place to store packaging, distributed or centralized storage facilities have been analysed and selected	1		
		Refilling infrastructure	Refilling infrastructure has been implemented	1		
		Tracking	The packaging can be tracked and monitored through dedicated technology	1		
USER DESIRABILITY	Packaging	Functional value	User perceive the reusable packaging as convenient	2		
		Financial value	User does not have to pay additional cost to use reusable packaging	2		
		Emotional value	Emotional value is communicated to the user	1		
		Lifestyle value	Lifestyle value is communicated to the user	2		
		Environmental value	Environmental value is communicated to the user	2		
	System design	User role	User has a clear understanding of its role in the system	2		
		User education	User has been clearly communicated instructions for use and reuse of the packaging	2		
		Return incentive	A dedicated strategy has been selected to drive high return rate (financial incentive, fee-based model, deposit scheme)	2		



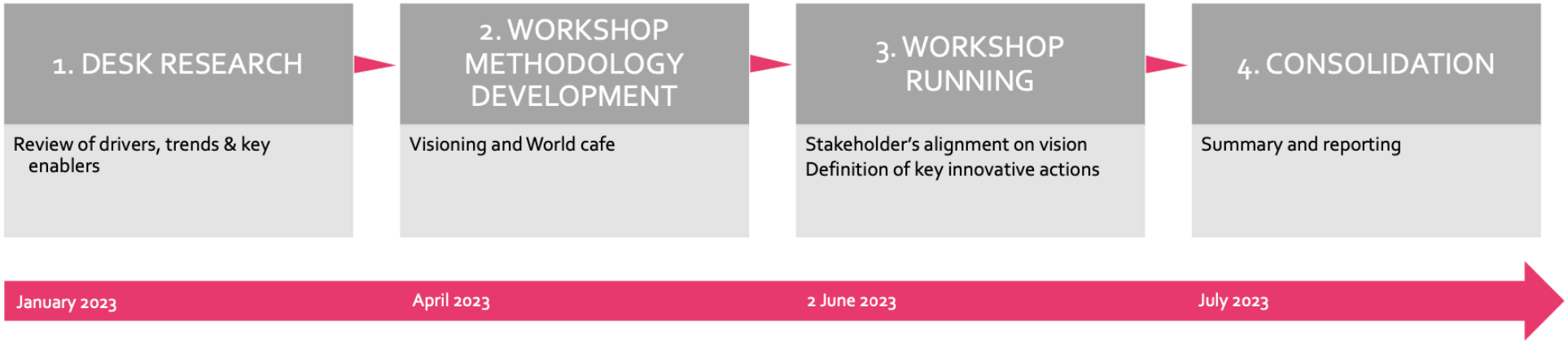
READINESS LEVEL	64,96 %

Technical feasibility	50,00 %
User desirability	93,75 %
Business viability	50,00 %
Sustainability	66,00 %
Scalability	50,00 %
Governance	80,00 %

T5.5 Roadmap

Objectives and task process

Objective: define future visions and roadmap for the upscaling of reusable systems



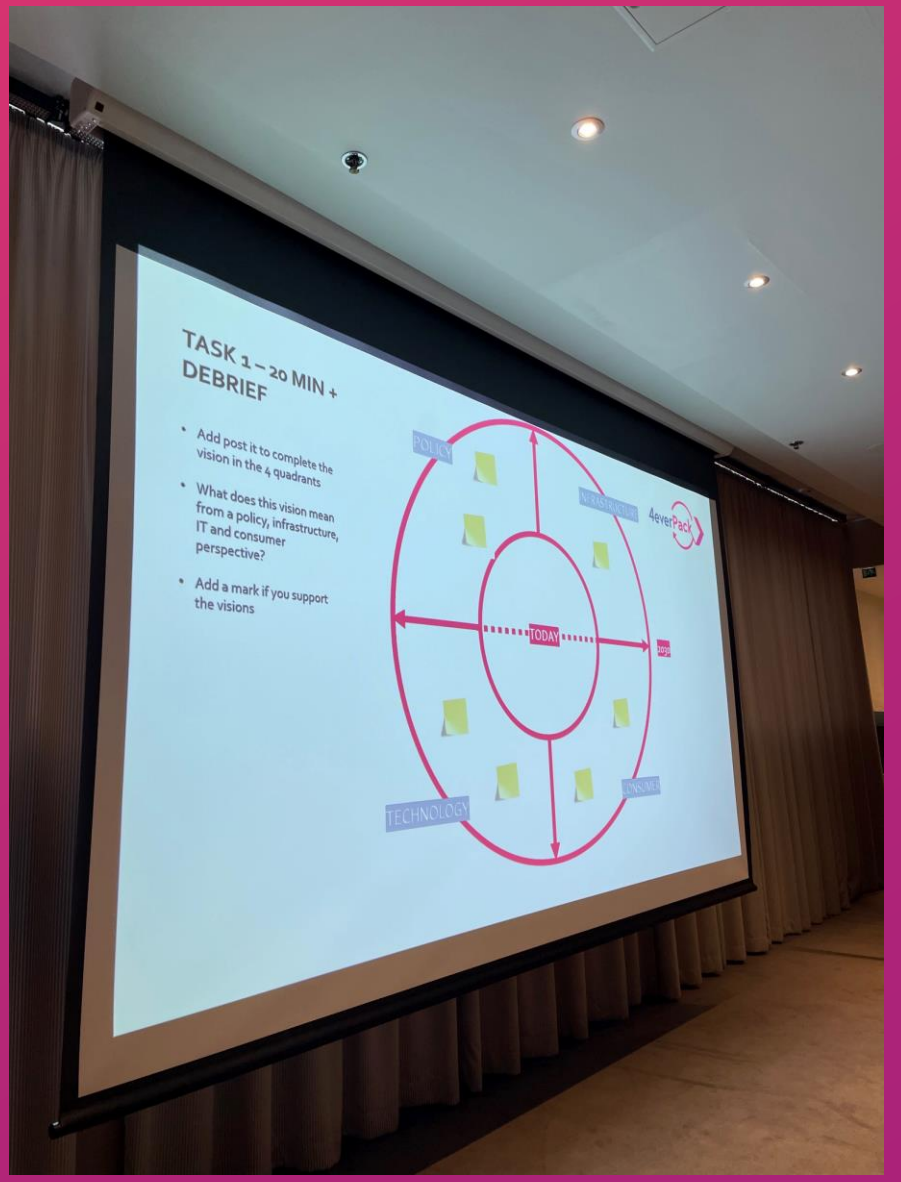
Key take aways

CONSUMER: multiply real-life experimentations, work on awareness and communication, research on mainstreaming niche innovation (tipping points of system change)

INFRASTRUCTURE: importance of ecosystem approach involving key logistics and washing actors. Work towards standardisation, pooling systems.

POLICY: regular screening at EU level, regulatory lobbing, future EPR schemes, green deal for reuse

TECH: standardisation of systems, platform integrations



To learn more…

Summary of the roadmap exercise is available by clicking on the cover

Available here

9.Conclusions

Conclusions

The transition to reusable packaging systems has the potential to reduce the negative environmental impact of single-use packaging. This transition however will need to be supported through:

- Technological advancements in connection to packaging materials, packaging design, traceability technologies
- Legislation resulting in paying of the real cost of the packaging (material use, cost of littering, cost of landfilling/incineration, cost of loss of biodiversity…)
- Investments / funding to innovate, experiment and scale reuse solutions in complex business ecosystems
- Increased consumer understanding and facilitation of reuse through concrete value propositions aligned with target consumers' preferences
- Supporting investments to build efficient reuse infrastructure