Circular Design

Unleashing New Revenue Streams for OEMs

Giovanni Formentini
Aarhus University

Circular Economy for Enterprises

DOKK1, Aarhus

01/03/2023

This project has received funding from the H2020 programme under Grant Agreement No. 958448

Speaker Overview

GIOVANNI FORMENTINI

Master Degree: Aeronautical Engineering

PhD: Industrial and Management Engineering in Complex Product Design Optimization

Currently: Research Scientist (PostDoc) AARHUS UNIVERSITY

Academic Collaboration

AARHUS UNIVERSITY

UNIVERSITÀ POLITECNICA DELLE MARCHE

UNIVERSITÀ DI PARMA

Scuola universitaria professionale della Svizzera italiana
SUPSI

POLITECNICO MILANO 1863

Industrial Collaboration

gorenje Life Simplified

ABB

AIRBUS

PLM4U CAD • PDM • PLM INTEGRATED SOLUTIONS

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Circular Economy for Enterprises

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the European Union

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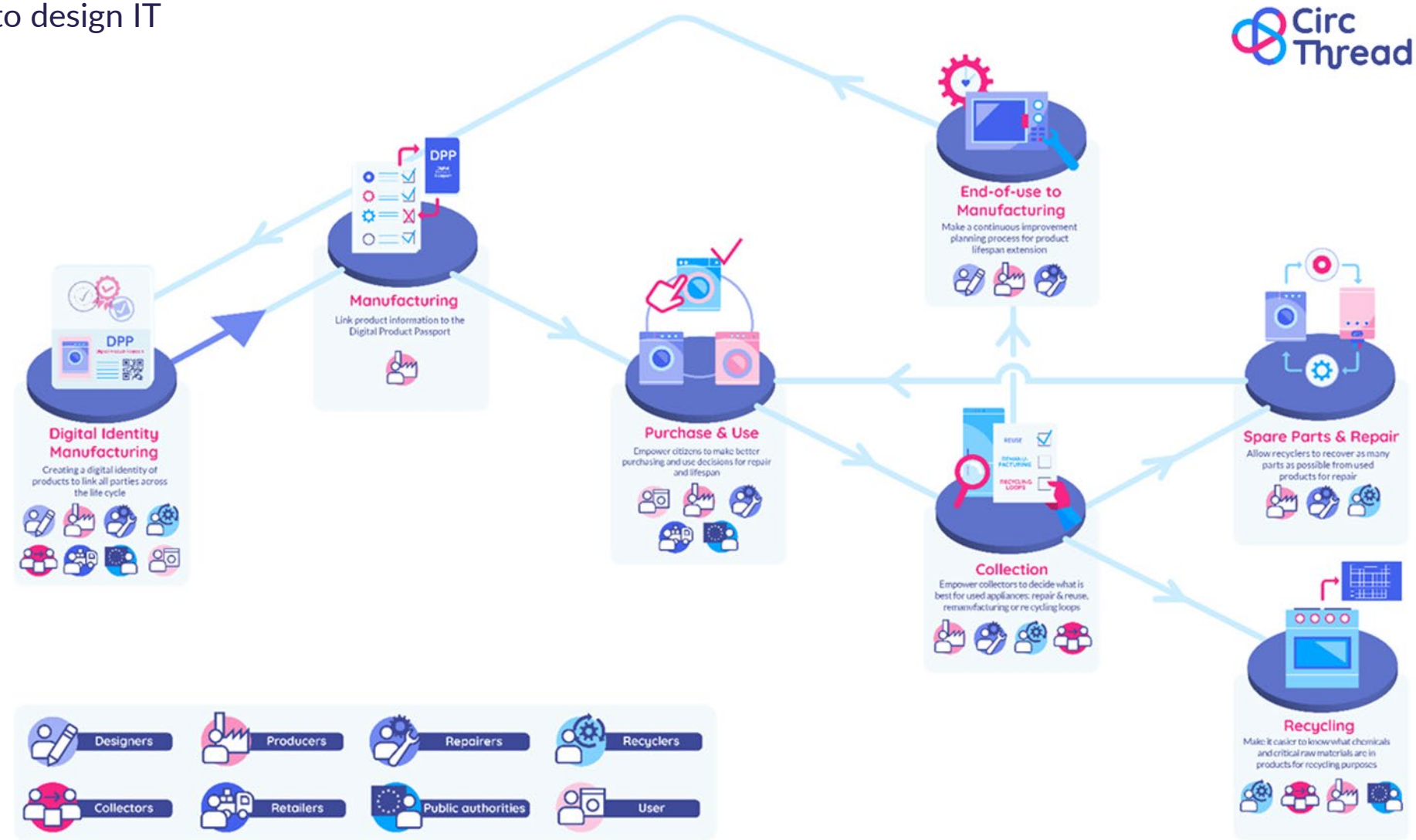
CircThread

The EU project to make appliances truly sustainable

32 partners working together to design IT services:

- to capture
- to manage
- to share

Product Information



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Circular Economy

Why now?

Environmental Reasons

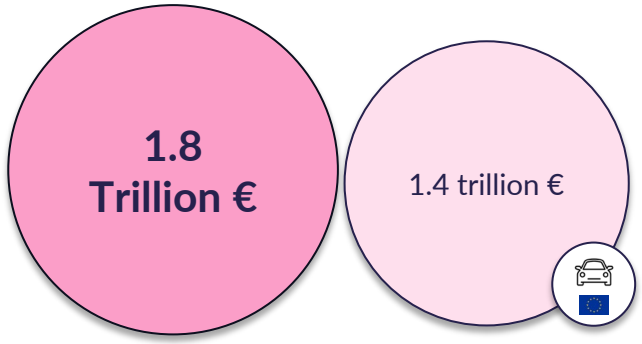
- The world population
- Resources are finite
- Need to protect the environment
- Need to reduce raw material dependence

Legislation Reasons

- European Union rules
  (*Circular Economy Action Plan*)
- Other countries following
  (*e.g. Japan - Circular Economy Vision 2020*)

Economical Reasons

- Expected Circular Economy Market
  1.8 trillion € in EU 2030
  (McKinsey&Company)

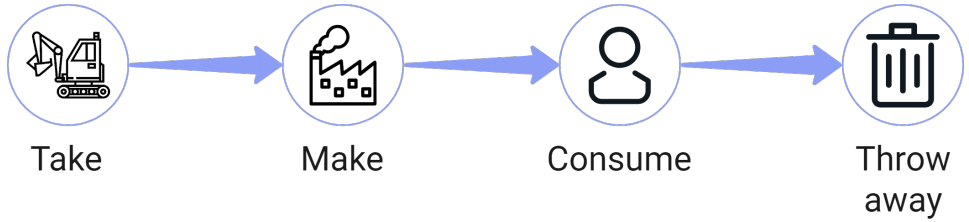


Circular Economy

Overview

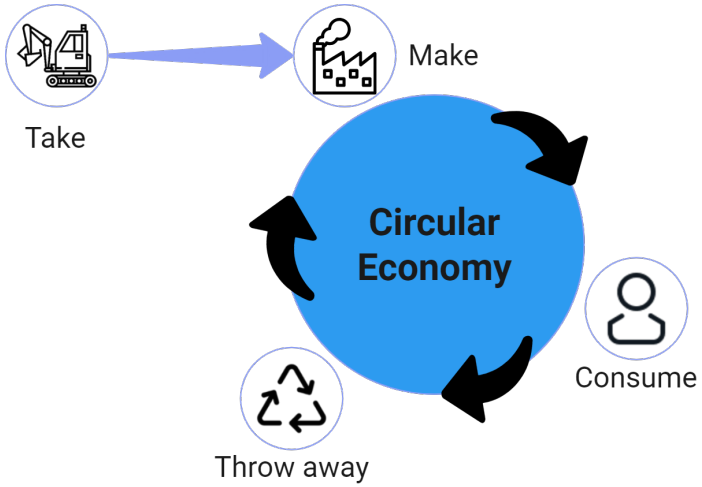
Linear Economy

- Extract materials from the Earth, manufacture products and ultimately discard them as waste.
- Environmental unsustainable
- Economical unsustainable (**one buy, one use**)



Circular Economy

- Minimize or eliminate waste production.
- Products and materials in use for as long as possible.
- Creation of a closed loop of resource utilization.
- Economical growth (**one buy, multiple use**)

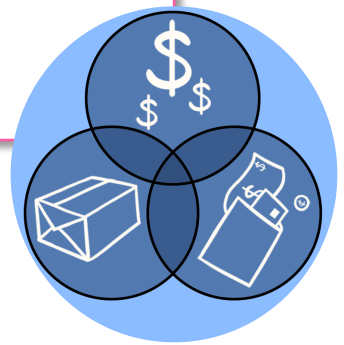


Circular Economy

Generate new revenues, how?

Circular Business Model

*How a company creates and **delivers value** to customers while **minimizing ecological and social costs**, in **exchange** for a **profit***



CBM examples

- Circular Supply
- Product life extension
- Sharing
- Resource recovery
- Product-service systems (PSS)

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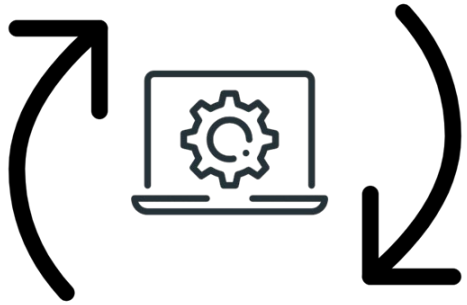
Circular Product Design
Definition

Circular Product Design

Focuses on the development of methods and tools that enable the design of products that are used more than once



Changing the Design of the product is **fundamental** for enabling **Circular Business Models**

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Circular Product Design

Definition

Product Range: Low to Medium Value ---------- Design Strategy: Planned Obsolesce within 3 years

Implementation Circular BM
Product Sharing – Collection after 2 years

No Design Change

Action	Gain	Loss
Company sells product	+1	

Begin of 1st year

With Design Change

Action	Gain	Loss
Company sells product	+1	

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No Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1

End of 2nd year

With Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1

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Action	Gain	Loss
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User uses it for 2 years	+1	
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Company inspects the product		-1

With Design Change

Action	Gain	Loss
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Action	Gain	Loss
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Company inspects the product		-1
Company changes target components		-1

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Company collects the product		-1
Company inspects the product		-1
Company sells product to another user	+1	

Begin of 3rd year

With Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1
Company inspects the product		-1
Company changes target components		-1
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Company collects the product		-1
Company inspects the product		-1
Company sells product to another user	+1	
Product breaks down		-1

With Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1
Company inspects the product		-1
Company changes target components		-1
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Product breaks down		-1
Company collects it		-1
Provides user with another one		-1

With Design Change

Action	Gain	Loss
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Company inspects the product		-1
Company sells product to another user	+1	
Product breaks down		-1
Company collects it		-1
Provides user with another one		-1
Company repairs it		-1

End of 3rd year

With Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1
Company inspects the product		-1
Company changes target components		-1
Company sells product to another user	+1	

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Company inspects the product		-1
Company sells product to another user	+1	
Product breaks down		-1
Company collects it		-1
Provides user with another one		-1
Company repairs it		-1

Gain 3
Loss -6

Total User Served
2

With Design Change

Action	Gain	Loss
Company sells product	+1	
User uses it for 2 years	+1	
Company collects the product		-1
Company inspects the product		-1
Company changes target components		-1
Company sells product to another user	+1	

Gain 3
Loss -3

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Disassembly as a key enabler for Product Circularity

Coercive products for Disassembly System

Products Design for Circularity **must**:

- Be designed considering the whole Disassembly System
- Consider product End-Of-Life Status

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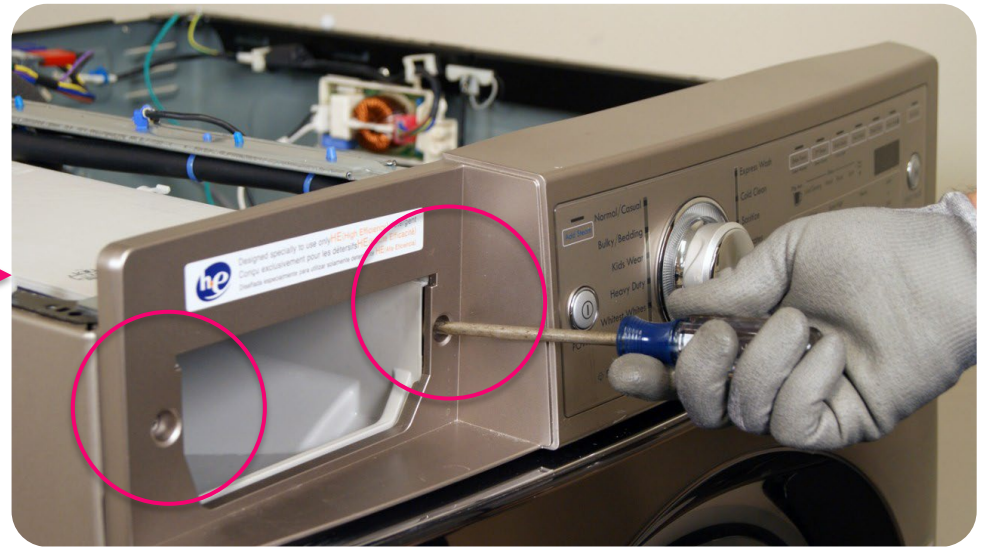

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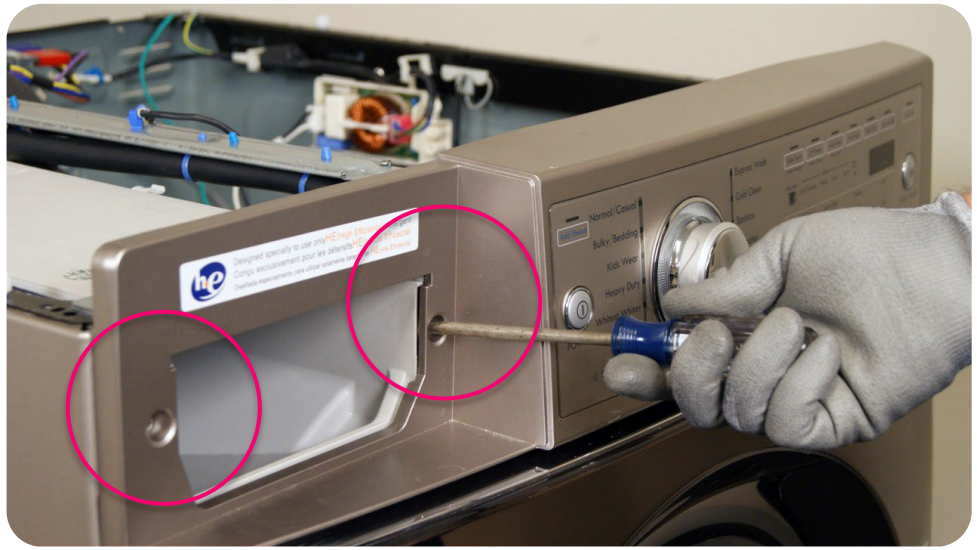

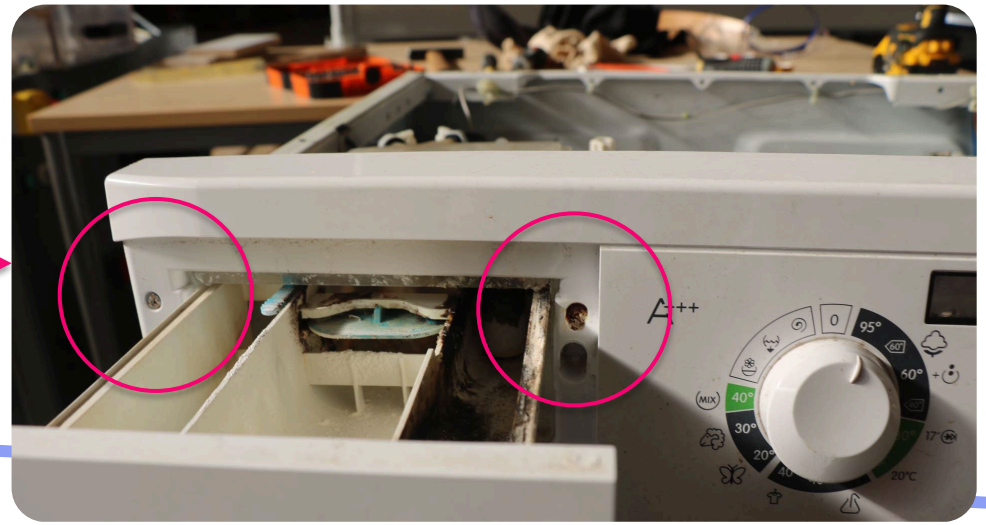

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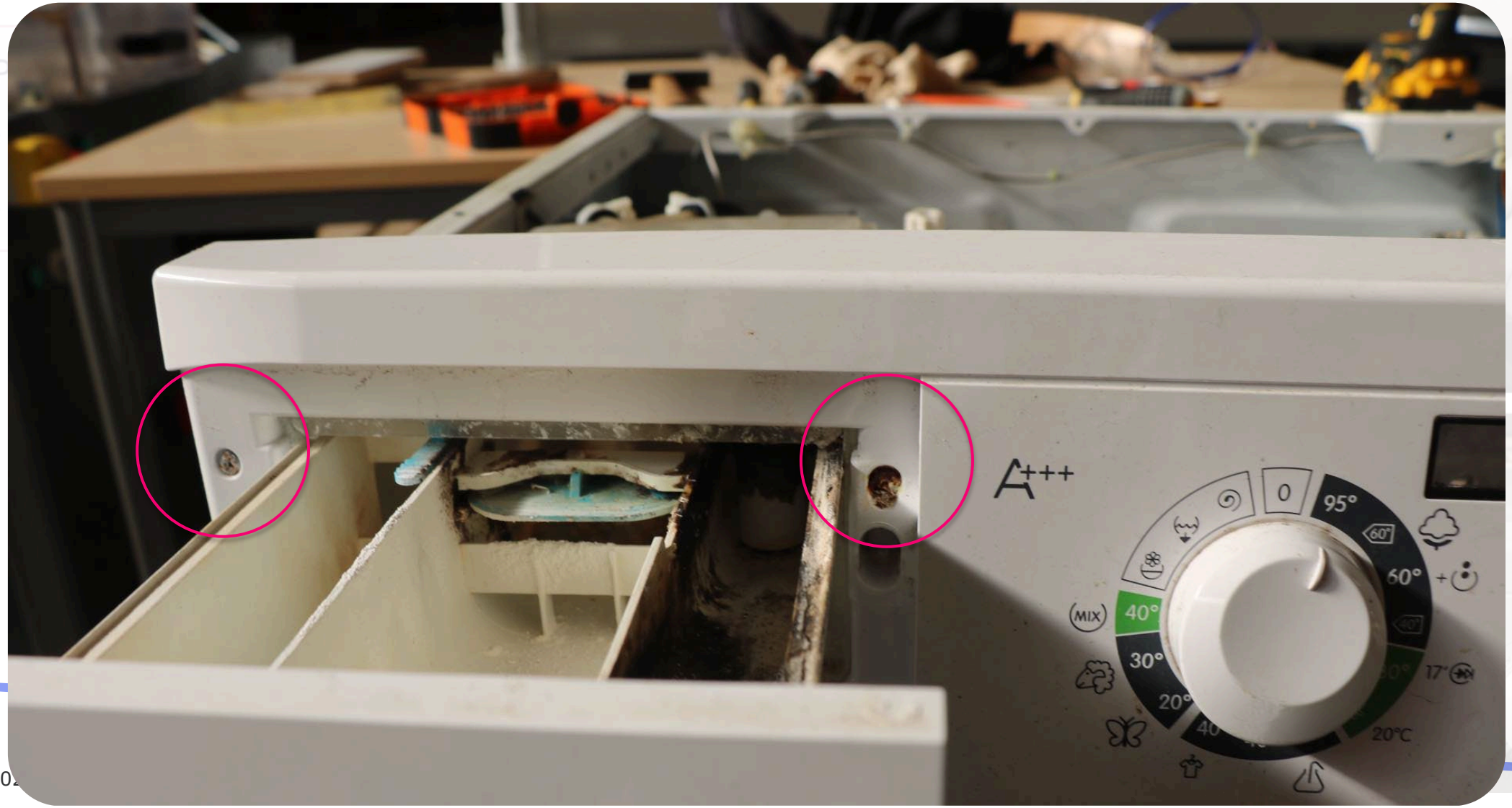

Design for Circular Disassembly
Overview

Design for Circular Disassembly [Formentini and Ramanujan, 2023]

State of Art methodology for improving product disassembly performances in terms of:

I. **Reparability** – *identify short comes in the product design that limits the disassembly for reparability*

II. **Circularity** – *identify disassembly failures in the product that might affect the disassembly of the product at its end-of-life*

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State of Art methodology for improving product disassembly performances in terms of:

I. **Reparability** – *identify short comes in the product design that limits the disassembly for reparability*

II. **Circularity** – *identify disassembly failures in the product that might affect the disassembly of the product at its end-of-life*

Key points

1) Consideration End of Life in the Product Design phase

2) Consideration of Disassembly Failures
"failures that have a direct impact on the disassembly process, and consequently impact the product circularity"

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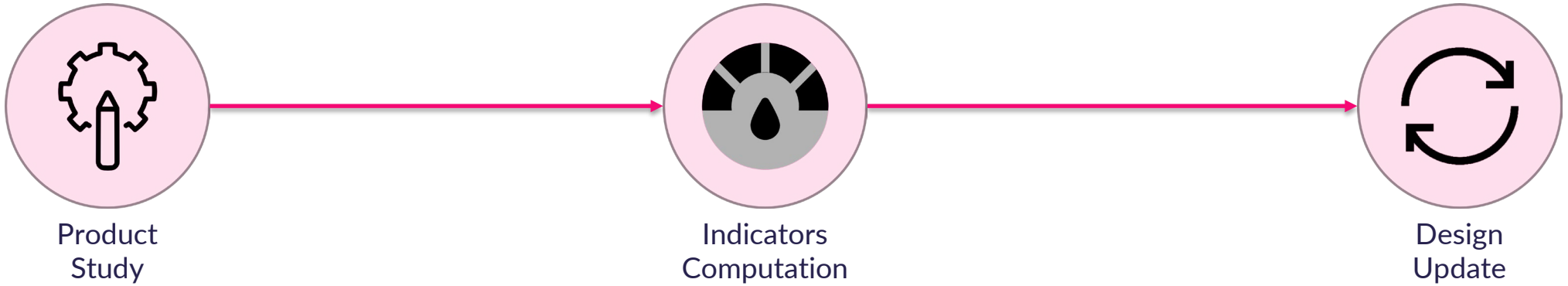
Design for Circular Disassembly
Overview

Design for Circular Disassembly [Formentini and Ramanujan, 2023]

Approach Overview



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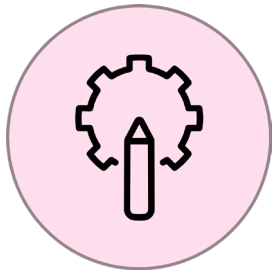

Product Study

Collect Product Information.

- Target Component
- Disassembly Steps
- Disassembly Failures

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Design for Circular Disassembly
Overview

Design for Circular Disassembly [Formentini and Ramanujan, 2023]

Approach Overview

Compute Indicators.

- Disassembly Performances (*Disassembly Effort Index)*
- Circularity Performances (*Circularity Index)*

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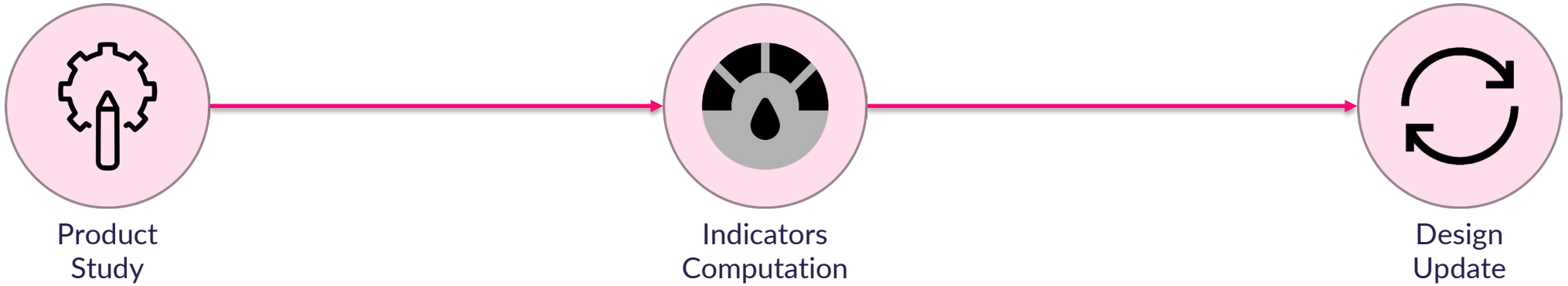
Design for Circular Disassembly
Overview

Design for Circular Disassembly [Formentini and Ramanujan, 2023]

Approach Overview



Design Update.

- Compute different Scenario (*if failure X happens, indicator Y increases)*
- Identify Components that need to be redesign
- Update Product Design

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Design for Circular Disassembly

Track Record

SIMPLE PRODUCT

Design for Circular Disassembly

Track Record

SIMPLE PRODUCT

Design for Circular Disassembly

Track Record

Disassembly Action	Disassembly Effort Index (DEI) - *seconds*	
	No Disassembly Failure	Disassembly Failure 1
	Perfect product	*Back screw rusted*
Separate	1,08	1,08
Unscrew	24,48	57,60
Disconnet	12,96	12,96
Unscrew & Remove	17,28	17,28
Unscrew	20,52	20,52
Unscrew	19,44	19,44
Remove	21,60	21,60
Disconnect	19,44	19,44
Unscrew	6,48	6,48
Unscrew	15,84	15,84
Remove	3,96	3,96
Unscrew	30,24	30,24
Remove	3,96	3,96
Unscrew	12,96	12,96

RESULT 1
Reparability Improvement

Disassembly Action	Disassembly Effort Index (DEI) - *seconds*	
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Disconnect	19,44	19,44
Unscrew	6,48	6,48
Unscrew	15,84	15,84
Remove	3,96	3,96
Unscrew	30,24	30,24
Remove	3,96	3,96
Unscrew	12,96	12,96

RESULT 2
Circularity Improvement

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Design for Circular Disassembly

Track Record

To improve product Reparability, redesign the most demanding action when the product is *perfect*.

Disassembly Action	Disassembly Effort Index (DEI) - *seconds*
	No Disassembly Failure
	Perfect product 
Separate	1,08
Unscrew	24,48
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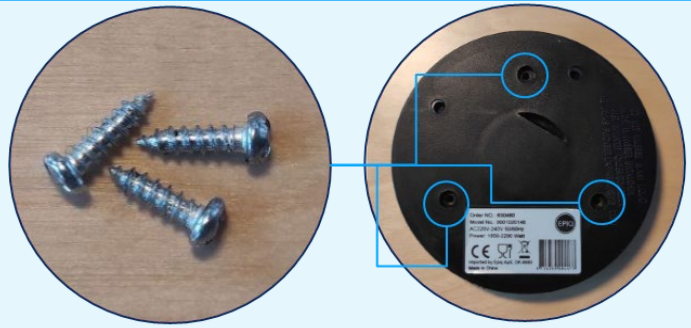

Redesign focus for **REPARABILITY**

Change the sheet metal screws with snap-fits, to improve reparability

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Design for Circular Disassembly

Track Record

To improve product Circularity, redesign the actions that are most demanding/require destructive actions when the product has *Disassembly Failures*.

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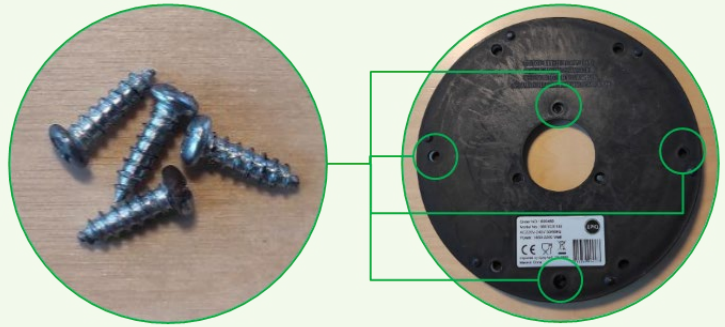

Redesign focus for **CIRCULARITY**

Change the tri-wings screws with stainless steel tri-wings, to improve circularity

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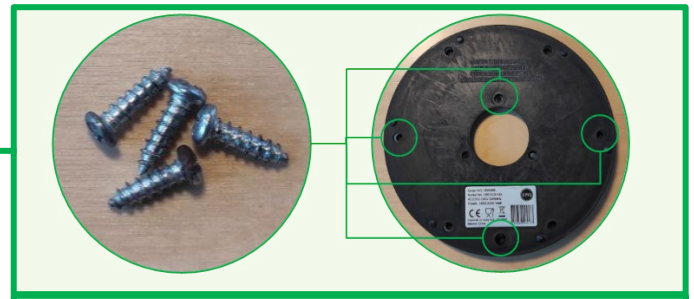
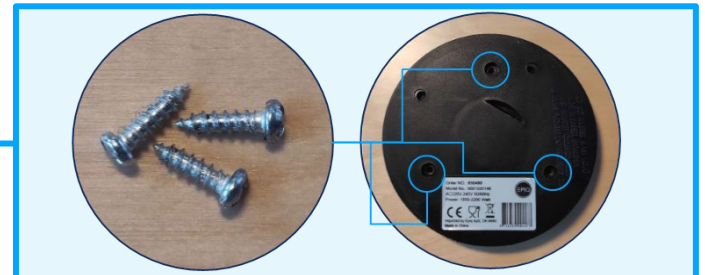


Improvement of Circularity Performances



Improvement of Reparability Performances

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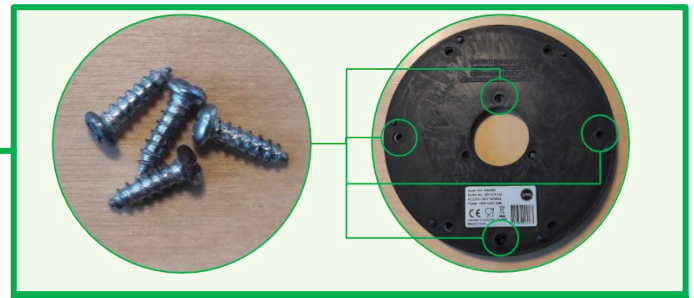
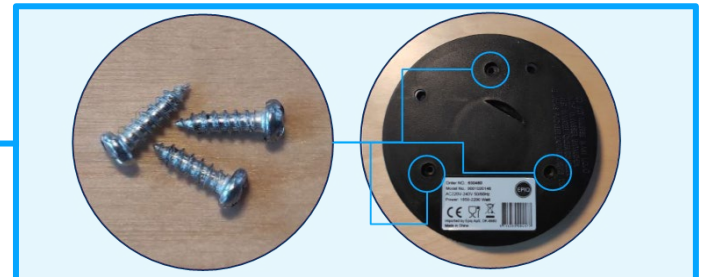
Different Goal

Different Focus



Improvement of Circularity Performances



Improvement of Reparability Performances

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Design for Circular Disassembly

Economic evaluation

Is Design Relevant?

			Disassembly Failure 1	
OEM				
Product Price	€	450,00	€	450,00

Assumptions

- Average Rate Operator 35€/h
- OEM Selling Price 450€
- Motor Price 15€

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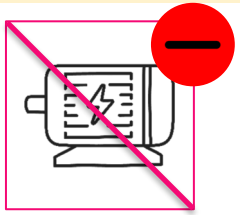
Design for Circular Disassembly

Economic evaluation

Is Design Relevant?

				Disassembly Failure 1	
OEM					
Product Price	€	450,00	€		450,00
OEM RECOVERY					
Disassembly Time (hour)		1			1,3
Disassembly Cost	€	33	€		47
Target Components Recovered		*All*		*All but Motor*	



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Design for Circular Disassembly

Economic evaluation

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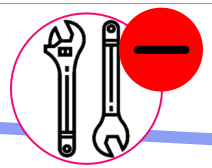
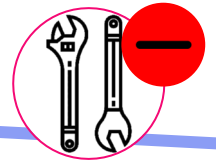
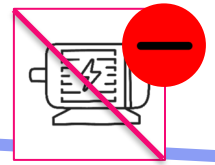
OEM RECOVERY					
Disassembly Time (hour)		1			1,3
Disassembly Cost	€	33	€		47
Target Components Recovered		*All*		*All but Motor*	
ECONOMIC EVALUATION					
Recovered Value					
Value obtained from the disassembly of the product	€	417	€		388







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Design for Circular Disassembly

Economic evaluation

Is Design Relevant?

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Disassembly Time (hour)			1		1,3	
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Target Components Recovered		*All*			*All but Motor*	
ECONOMIC EVALUATION						
Recovered Value *Value obtained from the disassembly of the product*	€		417	€	388	
Lost Opportunity Cost	€		-	€	14	*Increase of Disassembly Time*
Lost gain due to bad design				€	15	*New Motor Cost*
TOT	€		-	€	29	

Assumptions

- Average Rate Operator 35€/h
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- Motor Price 15€

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Design for Circular Disassembly

Economic evaluation

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				€	15	*New Motor Cost*
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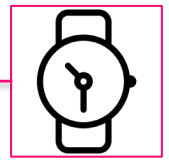

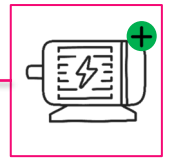

Assumptions

- Average Rate Operator 35€/h
- OEM Selling Price 450€
- Motor Price 15€

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Design for Circular Disassembly

Economic evaluation

Is Design Relevant?

Assumptions

- 10.000 Washing Machine/year

Disassembly % of WM	Economic	Perfect Conditions	Disassembly Failure 1
10%	*Recovered Value*	€ 416.808	€ 388.042
	Lost Opportunity Cost	*N/A*	€ 28.767
30%	*Recovered Value*	€ 1.250.425	€ 1.164.125
	Lost Opportunity Cost	*N/A*	€ 86.300
50%	*Recovered Value*	€ 2.084.042	€ 1.940.208
	Lost Opportunity Cost	*N/A*	€ 143.833
80%	*Recovered Value*	€ 3.334.467	€ 3.104.333
	Lost Opportunity Cost	*N/A*	€ 230.133
100%	*Recovered Value*	€ 4.168.083	€ 3.880.417
	Lost Opportunity Cost	*N/A*	€ 287.667

Design for Circular Disassembly

Economic evaluation

Is Design Relevant?

Assumptions

- 10.000 Washing Machine/year

Disassembly % of WM	Economic	Perfect Conditions	Disassembly Failure 1
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100%	*Recovered Value*	€ 4.168.083	€ 3.880.417
	Lost Opportunity Cost	*N/A*	€ 287.667

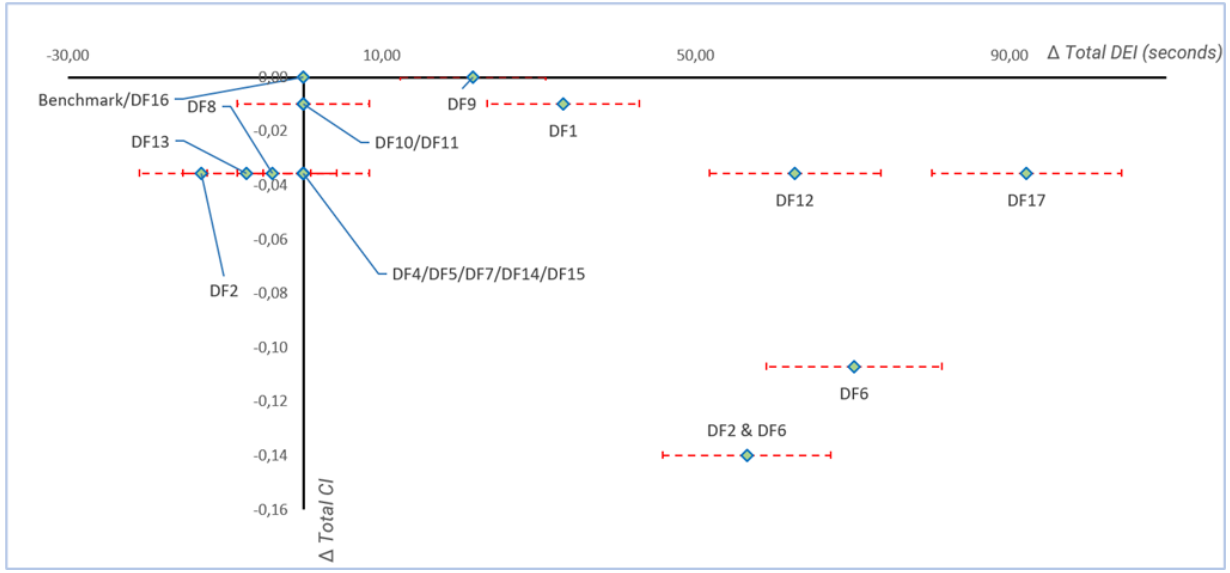
7%

Bad Design

Design for Circular Disassembly

Other considerations

- Disassembly Failures
  - More than 1 Disassembly Failure can happen at once
  - Need to consider *Statistical Information* about the product
  - Need to have a flux of products to analyze
  - Required access to the right data



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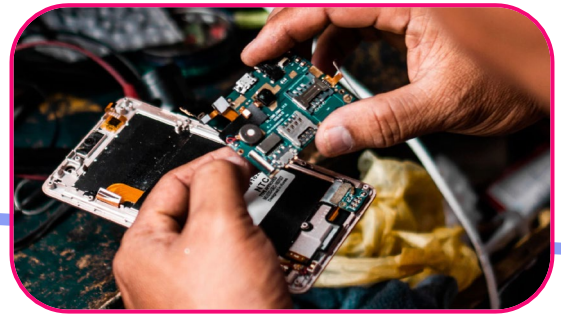
Design for Circular Disassembly

Other considerations

- Disassembly Failures
  - More than 1 Disassembly Failure can happen at once
  - Need to consider *Statistical Information* about the product
  - Need to have a flux of products to analyze
  - Required access to the right data
- Economical Benefits
  - Critical Raw Material
    - Upcoming Value (…*we live in a world with finite resources)*
  - Component Reuse for
    - New Product
    - Refurbish Products
    - Reduce warehouse capacity
    - Extend Customer Support



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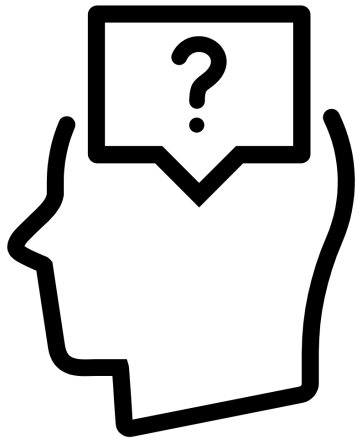
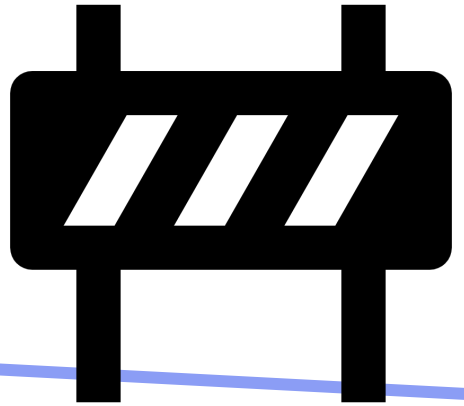
Design for Circular Disassembly

Limitations and barriers

- Data information exchange among stakeholders
  Product End-of-Life Condition? Recyclers?
- Data availability inside the company and at the right time
  Disassembly information available when the product is designed? Disassembly steps? Target Components? Disassembly time?
- Lack of system understanding
  How will the change in my product design affect the disassembly process? How is the reverse logistics? How will affect recyclers? Customers?
- Fast Product Development Processes
  Short development phases, Fast lead time
- Big company structures
  Cross-Department collaboration Deep changed to whole structure





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Circ Thread

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Thank you.

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