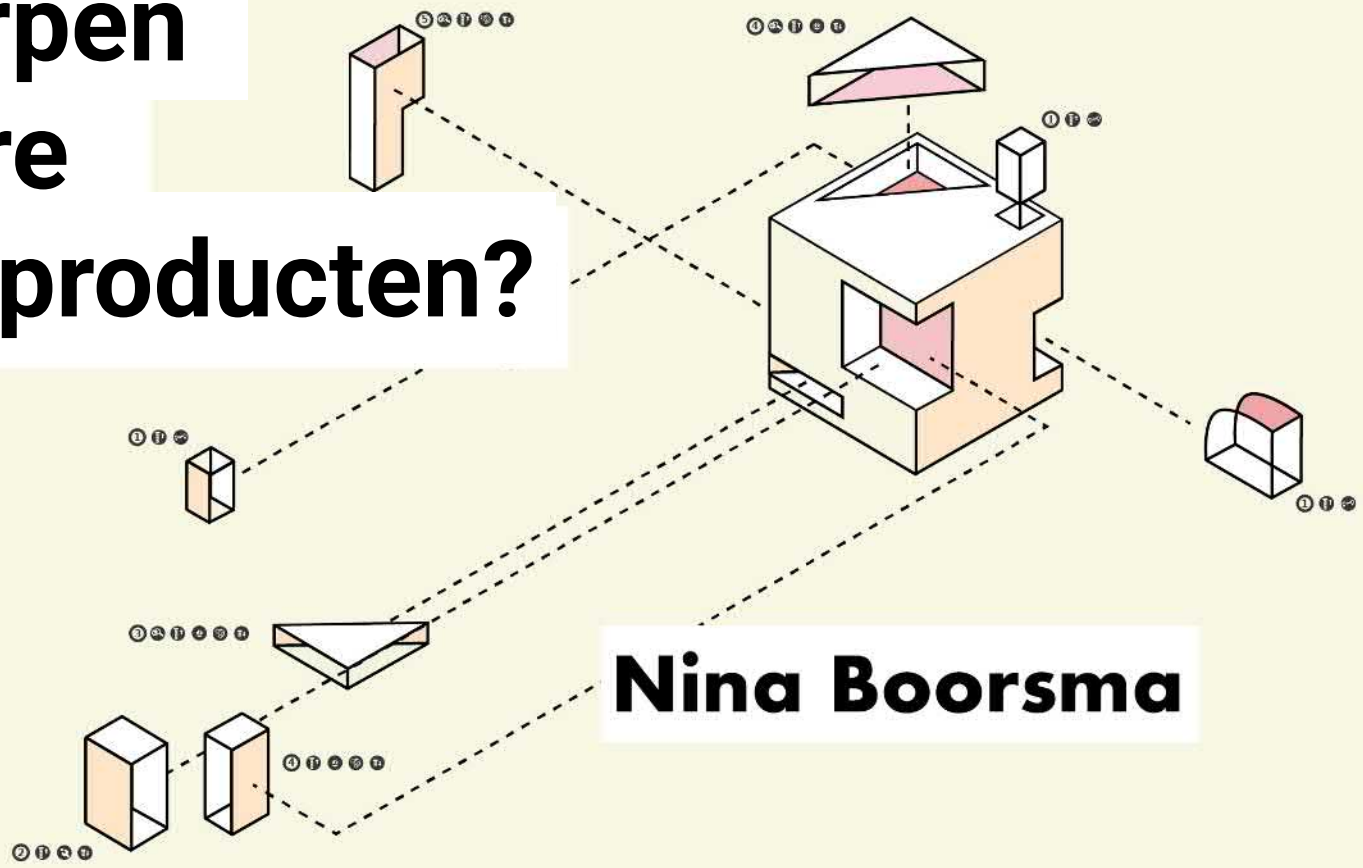
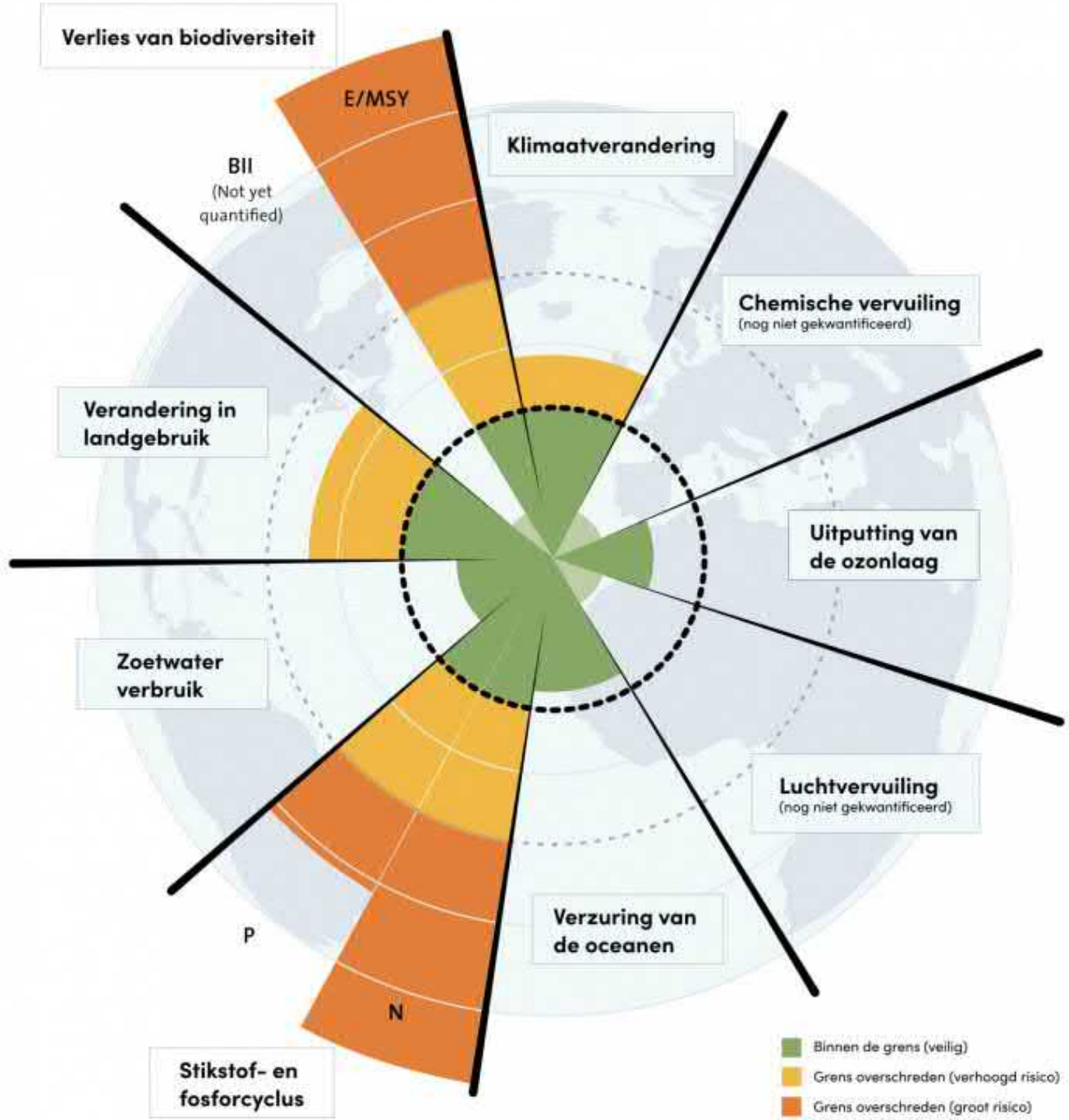
Hoe ontwerpen we circulaire industriële producten?

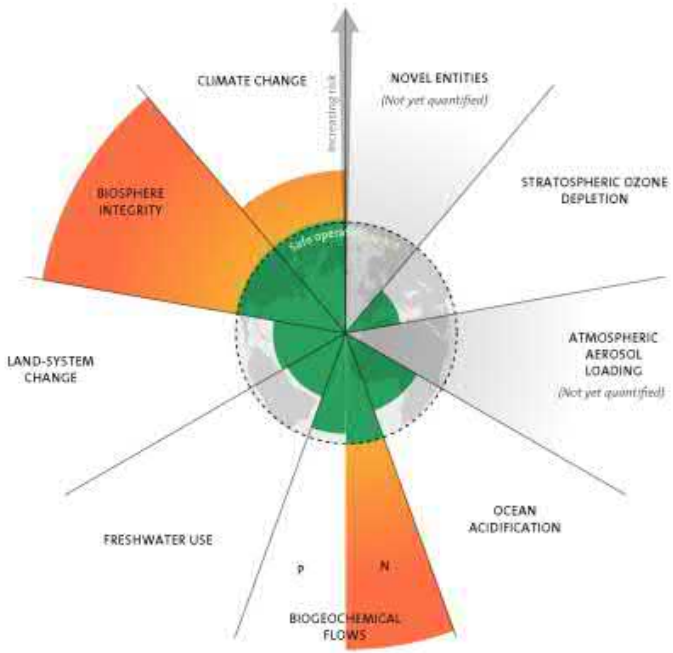


Nina Boorsma

TU Delft | DfS

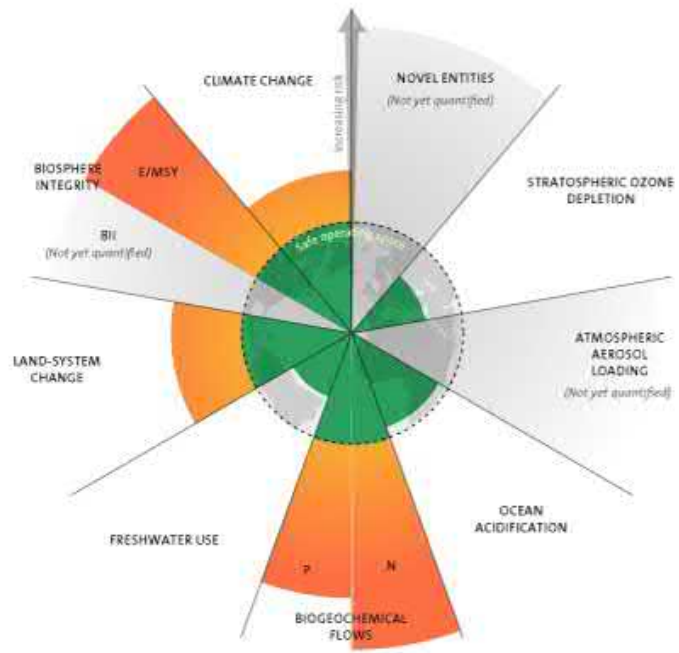

Verlies van biodiversiteit
E/MSY
BII
(Not yet quantified)
Klimaatverandering
Chemische vervuiling
(nog niet gekwantificeerd)
Verandering in landgebruik
Uitputting van de ozonlaag
Zoetwater verbruik
Luchtvervuiling
(nog niet gekwantificeerd)
Verzuring van de oceanen
P
N
Stikstof- en fosforcyclus
Binnen de grens (veilig)
Grens overschreden (verhoogd risico)
Grens overschreden (groot risico)

2009



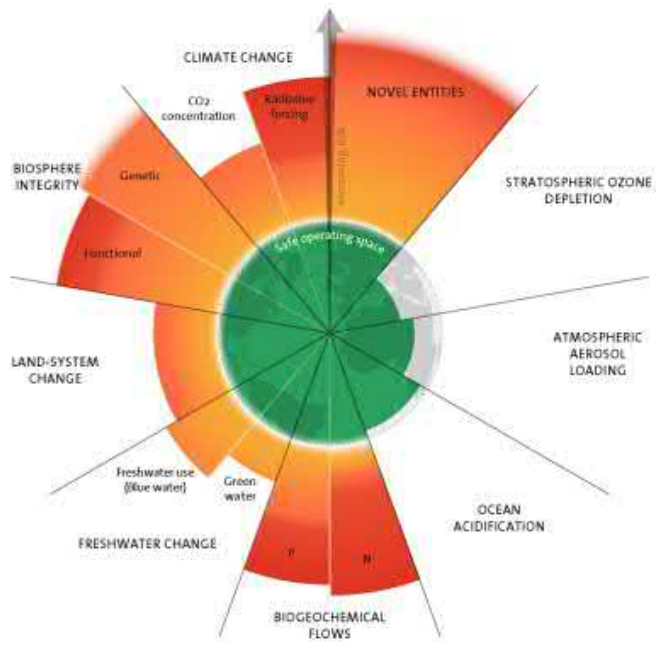
3 boundaries crossed

2015

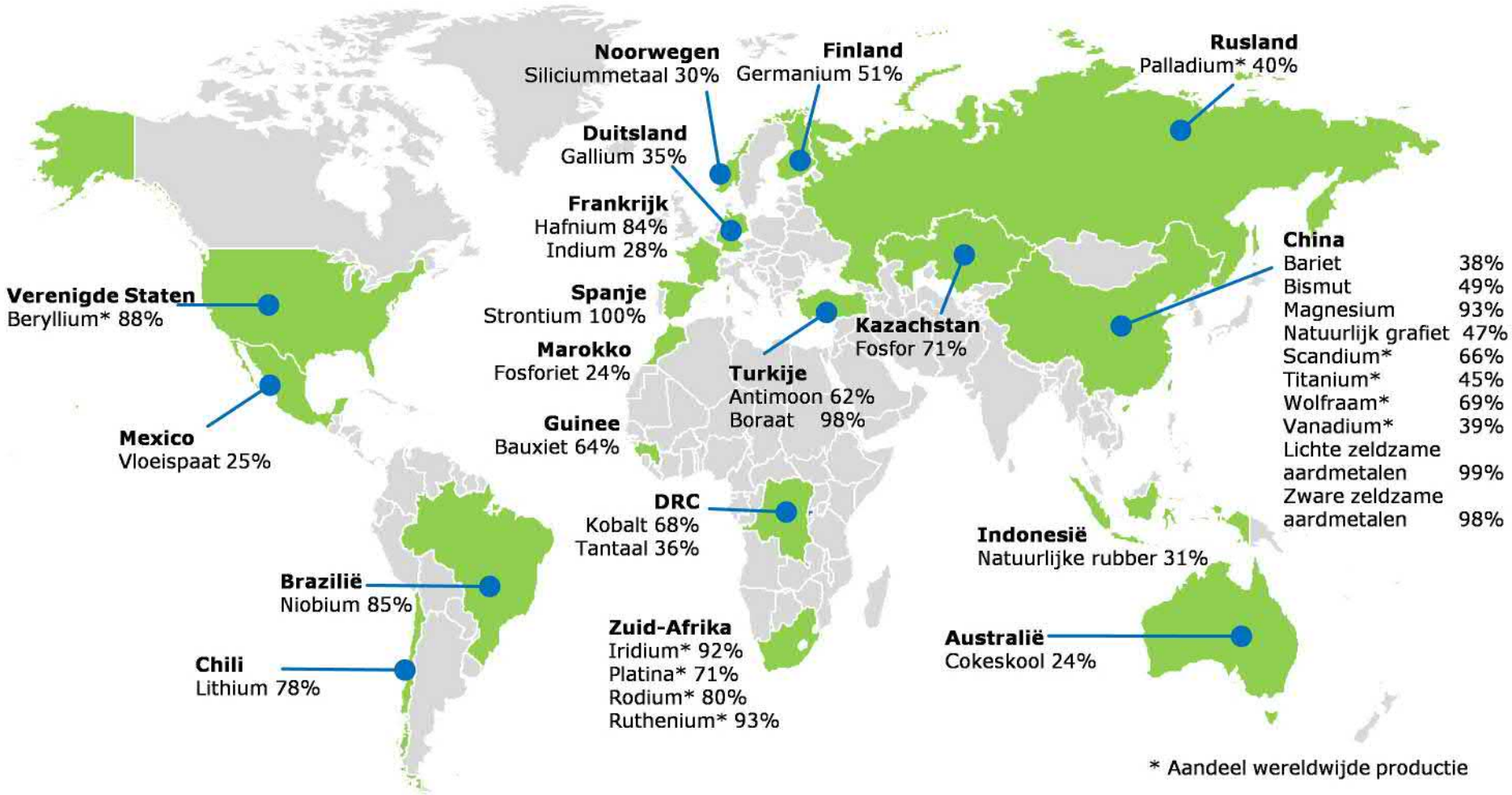


4 boundaries crossed

2023



6 boundaries crossed


Noorwegen
Siliciummetaal 30%
Finland
Germanium 51%
Rusland
Palladium* 40%
Duitsland
Gallium 35%
Frankrijk
Hafnium 84%
Indium 28%
Spanje
Strontium 100%
Marokko
Fosforiet 24%
Verenigde Staten
Beryllium* 88%
Mexico
Vloeispaat 25%
Guinee
Bauxiet 64%
Turkije
Antimoon 62%
Boraat 98%
Kazachstan
Fosfor 71%
China
Bariet 38%
Bismut 49%
Magnesium 93%
Natuurlijk grafiet 47%
Scandium* 66%
Titanium* 45%
Wolfraam* 69%
Vanadium* 39%
Lichte zeldzame aardmetalen 99%
Zware zeldzame aardmetalen 98%
DRC
Kobalt 68%
Tantaal 36%
Indonesië
Natuurlijke rubber 31%
Brazilië
Niobium 85%
Chili
Lithium 78%
Zuid-Afrika
Iridium* 92%
Platina* 71%
Rodium* 80%
Ruthenium* 93%
Australië
Cokeskool 24%
* Aandeel wereldwijde productie

Verordening kritieke grondstoffen

Europese Commissie https://eur-lex.europa.eu/legal-content/NL/TXT/HTML/?uri=CELEX%3A52020DC0474

Ruimtevaart/ Defensie	Textiel	Elektronica	Mobiliteit/ Automobiel	Energie-intensieve industrie	Duurzame energie	Agrovoedings-industrie	Gezondheids-zorg	Digitaal	Bouwnijverheid	Detailhandel	Nabijheid/ sociale economie	Toerisme	Creatieve/ culturele sectoren
Antimoon	✓	✓		✓						✓			
Bariet				✓	✓			✓		✓			
Bauxiet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Beryllium	✓		✓	✓		✓			✓				
Bismut	✓		✓		✓			✓	✓	✓			
Boraat	✓		✓	✓	✓	✓	✓		✓	✓			
Kobalt	✓	✓	✓	✓	✓	✓			✓				
Cokeskolen				✓	✓	✓							
Vloeispaat					✓		✓				✓		
Gallium	✓		✓	✓		✓			✓	✓			
Germanium	✓		✓		✓	✓							
Hafnium	✓		✓		✓	✓			✓				
Indium	✓		✓			✓			✓				
Lithium	✓		✓	✓	✓	✓		✓	✓				
Magnesium	✓		✓	✓	✓				✓	✓			
Natuurlijk grafiet	✓		✓	✓	✓	✓			✓	✓			
Natuurlijke rubber	✓	✓		✓				✓					
Niobium	✓		✓	✓	✓			✓		✓			
Fosforiet					✓		✓						
Fosfor	✓				✓		✓						
Scandium	✓			✓		✓							
Siliciummetaal	✓	✓	✓	✓	✓	✓		✓		✓			

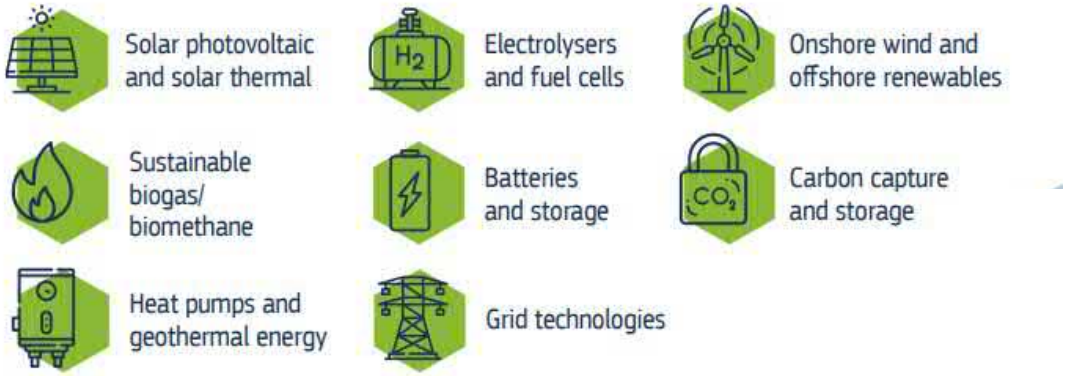
+8 ↓

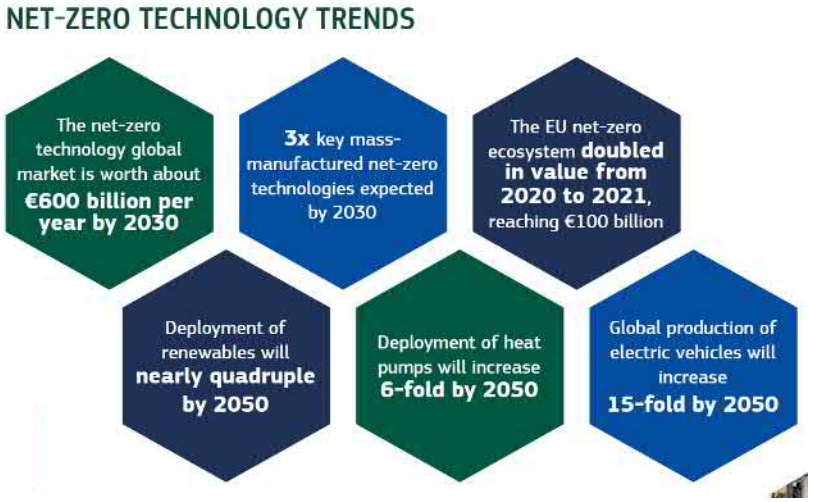
Benchmarks voor de Wet Kritieke Grondstoffen:
≥ 10% van het jaarlijkse verbruik in de EU voor winning
≥40% van het jaarlijkse verbruik in de EU voor verwerking
≥ 15% van het jaarlijkse verbruik in de EU voor recycling
≤ niet meer dan 65% van het jaarlijkse verbruik in de EU afkomstig uit één enkel derde land

Europese Commissie https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan/net-zero-industry-act_nl

Verordening nettonulindustrie

Vergroten van het concurrentievermogen van de industrie met klimaatneutrale technologie.





Net-Zero Industry Act

+8 ↓

Trends kritieke materialen

1.Diversificatie van toeleveringsketens

2.Recycling en circulaire economie

3.Onderzoek naar vervangende materialen

4.Urban Mining en secundaire bronnen

5.Duurzame mijnbouwpraktijken

6.Technologische vooruitgang in extractie

7. Internationale samenwerking

8.Regelgevende initiatieven

9. Impact van de energietransitie

10.Geavanceerde materiaalwetenschap

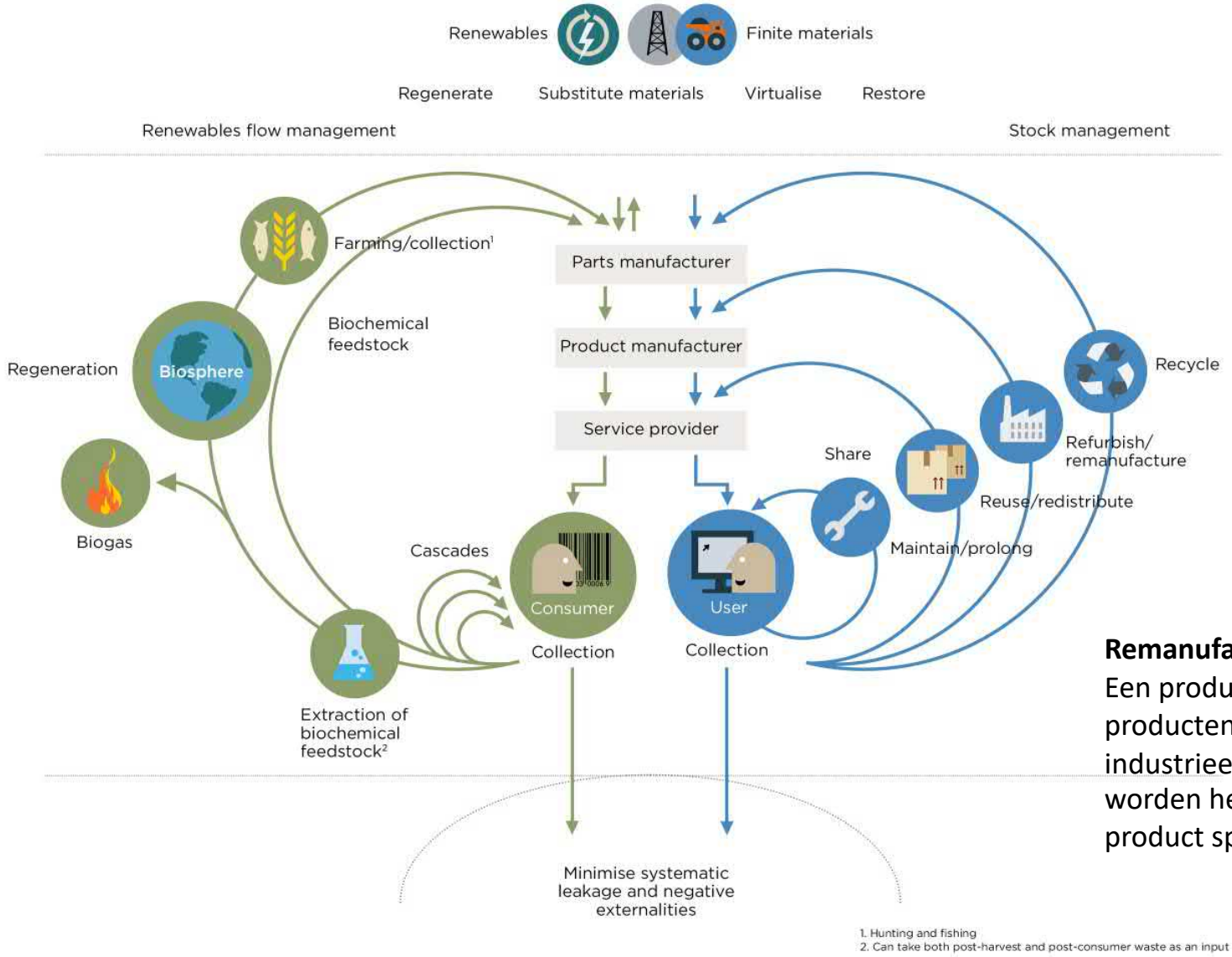
Drie principes
van de circulaire economy

Afval en vervuiling elimineren

Producten en materialen circuleren

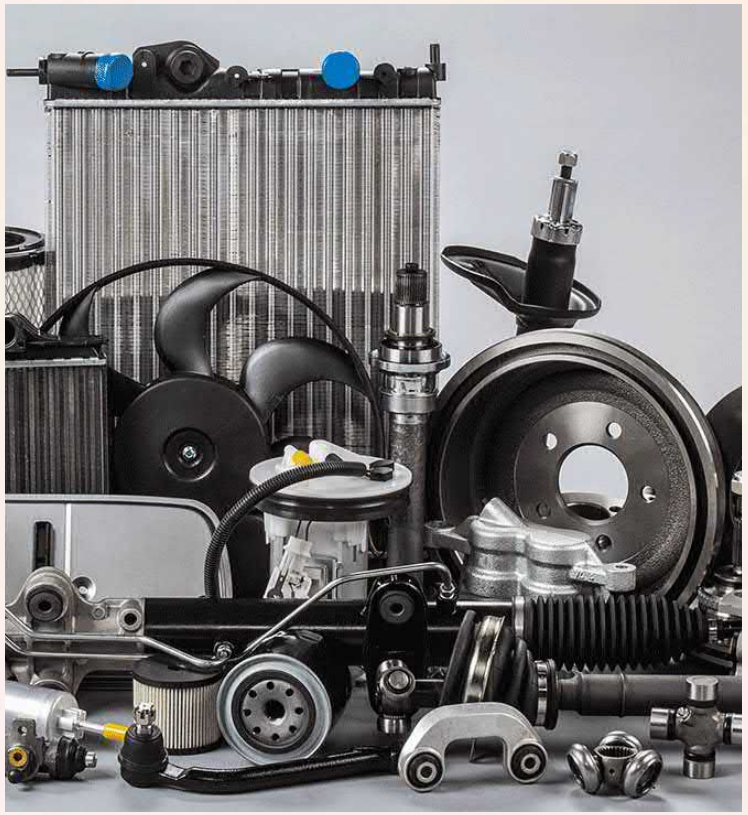
De natuur regenereren

“The problem, and the solution, start with design”
- Ellen MacArthur Foundation

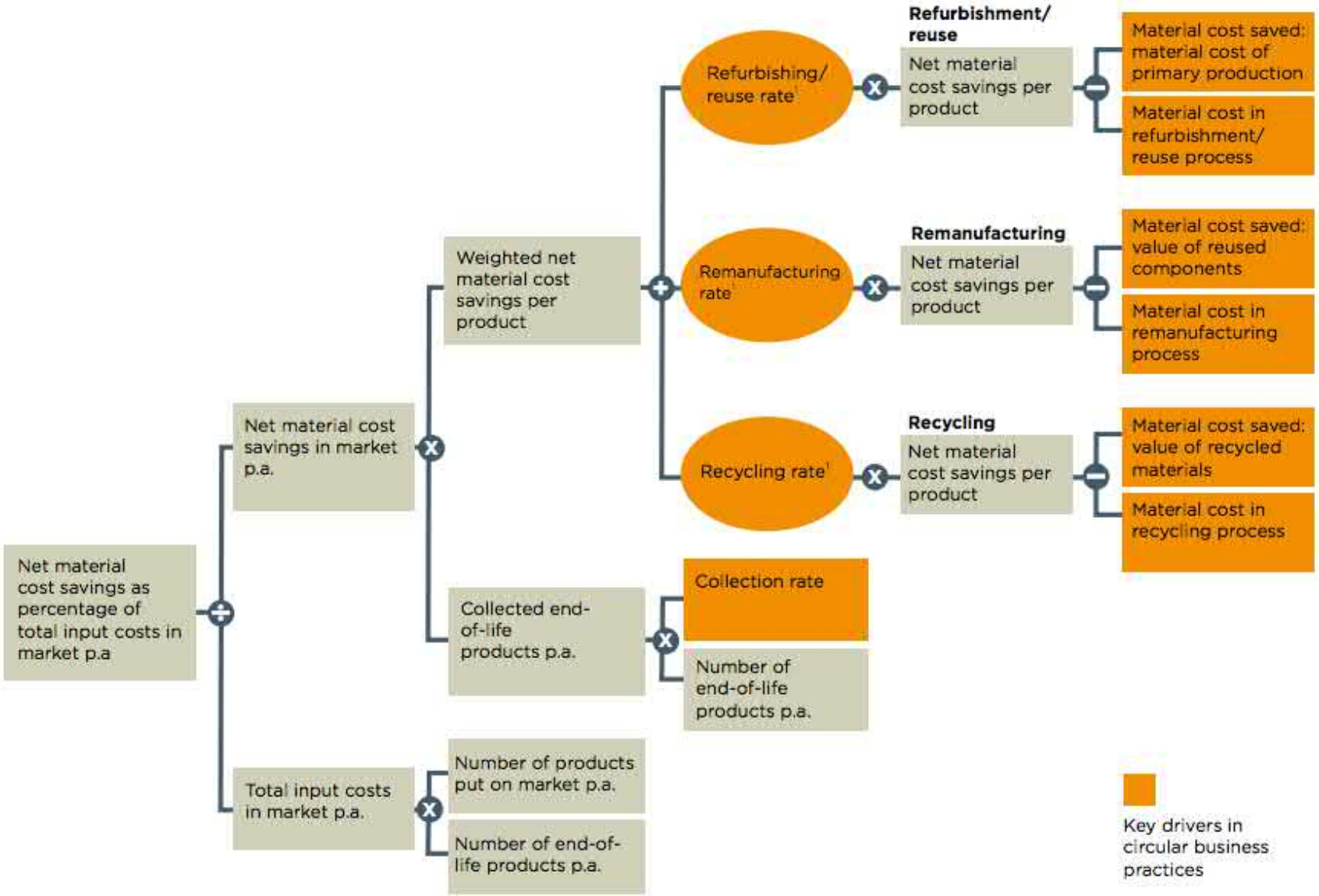


Remanufacturing
Een productieproces waarbij gebruikte producten een gestandaardiseerd industrieel proces doorlopen en worden hersteld tot de oorspronkelijke product specificatie.

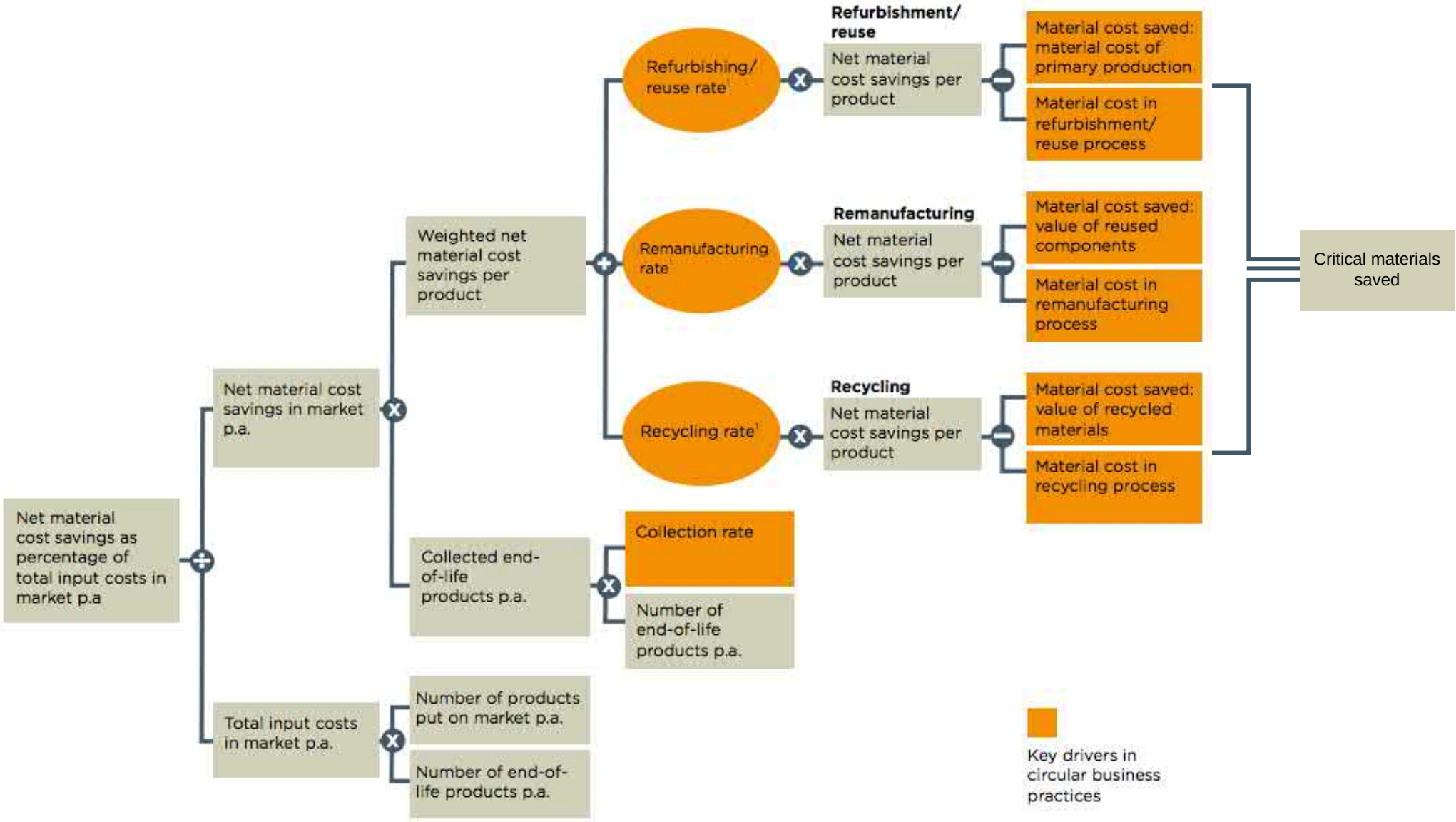
Productvoorbeelden




Selectie van gebruikte apparatuur
De-installatie, verpakken en verzenden
Remanufacturing
Opnieuw op de markt brengen en installeren van het geherfabriceerde apparatuur
Professionele diensten



1 Rates as percentage of collected products; add up to 100%
SOURCE: Ellen MacArthur Foundation circular economy team



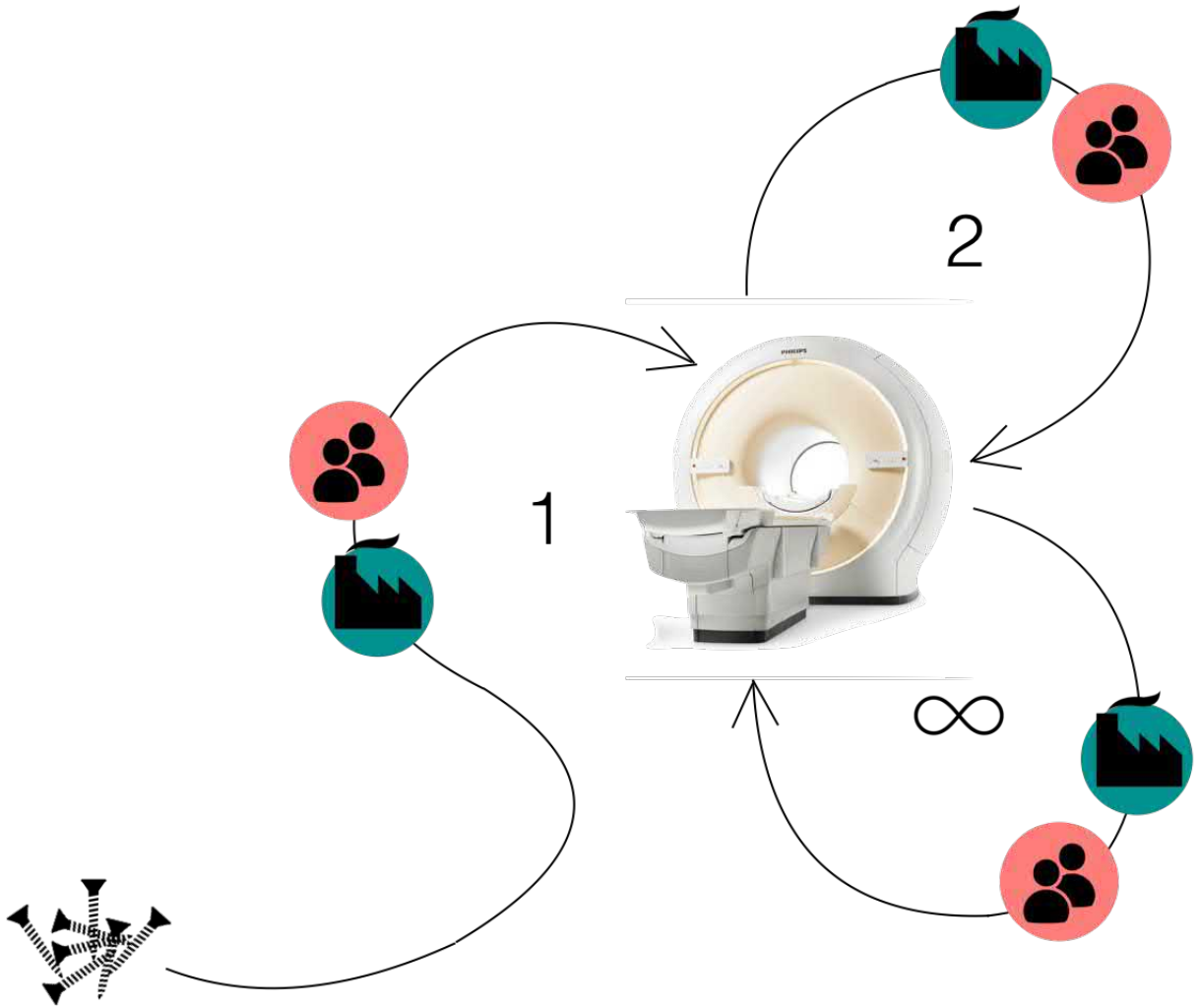
1 Rates as percentage of collected products; add up to 100%
SOURCE: Ellen MacArthur Foundation circular economy team

Casestudy: Medische systemen

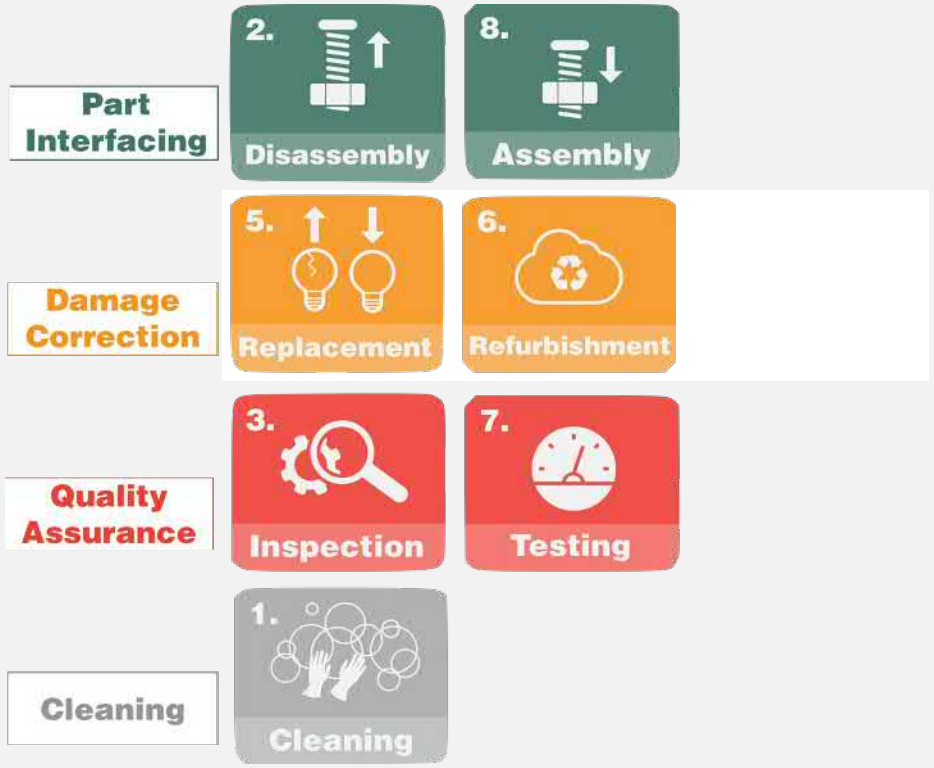
Link master thesis

Röntgen inspectiesystemen

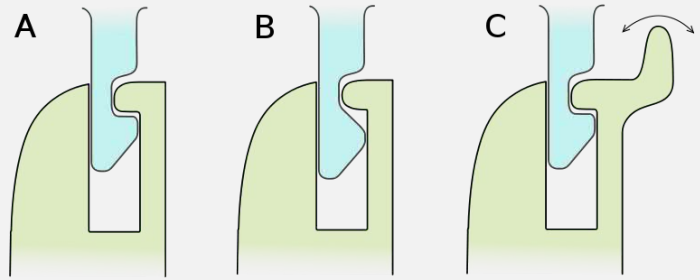
Magnetic Resonance Imaging (MRI)


2
1
∞

Design guidelines



Design guidelines



Category	Design guidelines
Part interfacing (1) Concerns component level; Assembly, Disassembly	1.2 Reduce total number of parts 1.3 Reduce quantity and variety of fasteners 1.4 Identify access points 1.5 Minimize number of joints 1.6 Use modular structure so that obsolescence occurs with rather than with entire product 1.7 Structure for ease of access to short life and prone to break down parts 1.8 Reduce tools required for disassembly […]
Damage correction (2) Concerns component level; Repair, Replacement and Refurbishment	2.1 Structure to facilitate ease of upgrade of a product […] 2.2 Isolate expected damage to removable and replaceable parts . […]
Quality assurance (3) Concerns performance level; Testing and Inspection	3.1 Clearly identify component load, limits, tolerances and adjustments […]
Cleaning (4) Concerns performance level	4.1 Arrange components so that all can be accessed for effective cleaning 4.2 Reduce/ eliminate redundant parts […]

Workshop

Sub modules

- L-arm
- C-arc
- Patient table
- System cabins
- User interface
- Flat detector
- X-ray tube

Design guidelines

Design guidelines

Technical room

Design rules mainly concerning the system cabins and content

- General
- Suspension system
- Technical room
  - Compatibility
  - Modularity
  - Damage precautions
  - Part lifetime
- Treatment table
- Tube and flat detector
- User interface

Configurations
Keep [...]

Configurations
Increase the [...]

Modularity
Keep material [...]

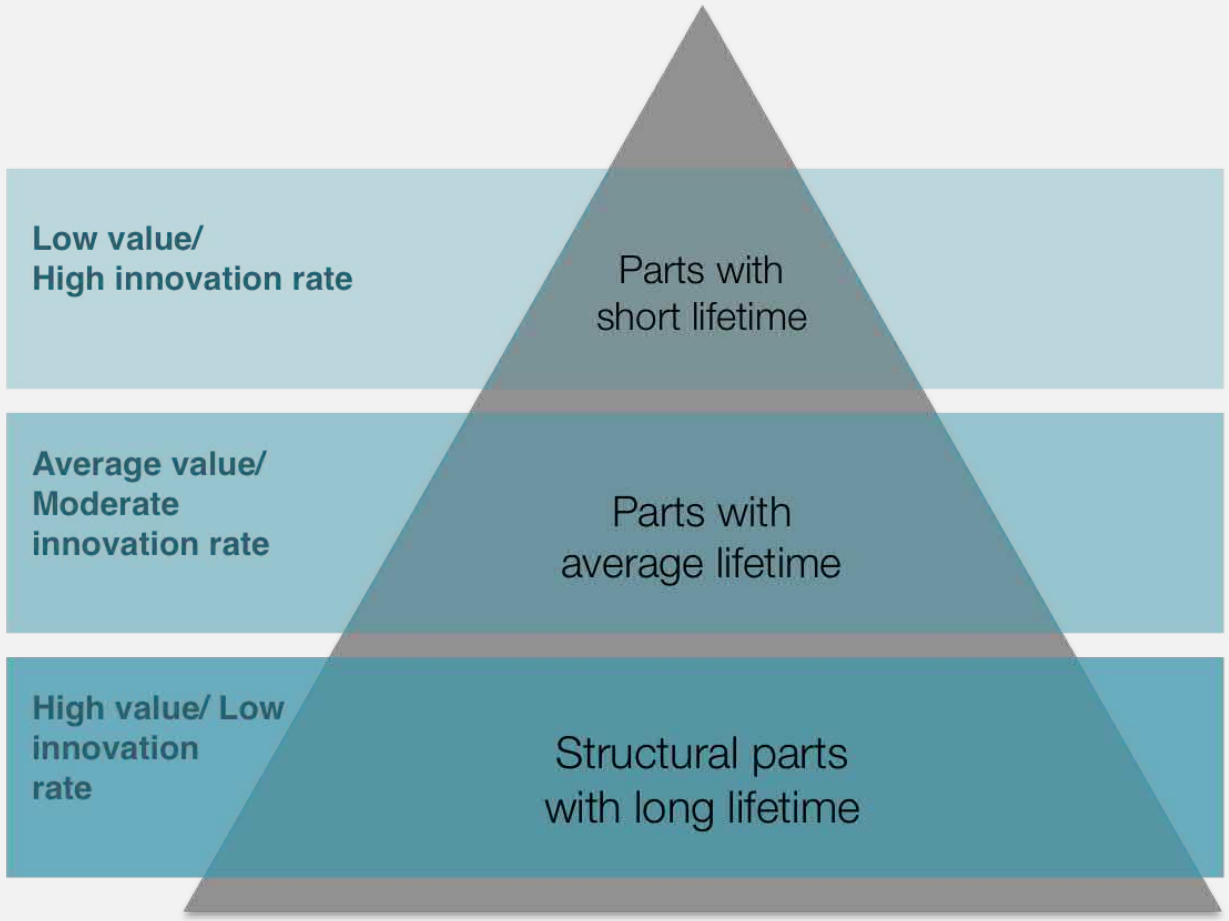
Cabling
Design parts so [...]

Cabling
- [...] cabling
- Maintain [...]

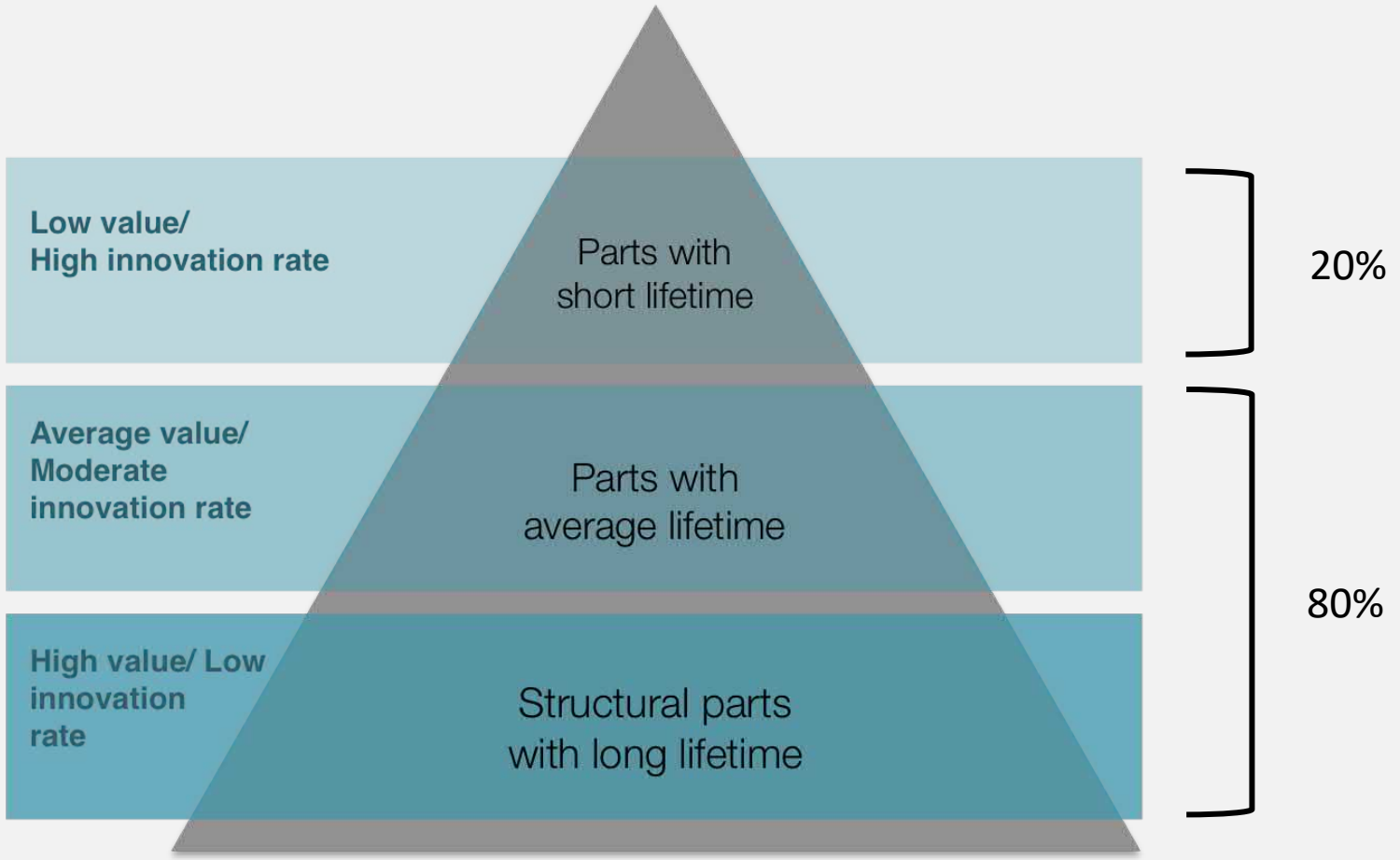
Modularity
Design [...]

Configurations
Keep [...] at a minimum

Part lifetimes



Part lifetimes



S.W.O.T.

All chapters

What the market and the company is concerned, the following strengths (S), weaknesses (W), opportunities (O) and threats (T) were found and clustered together below (some were shortened). This overview summarizes and concludes what was discussed in all chapters.

INTERNAL FORCES

S

1. Highly suitable for product-service-systems
2. Healthier and more sustainable world
3. Unstable prices of raw materials
4. Good portfolio management
5. High quality and performance
6. High residual value of medical systems
7. Adequate marketing tool
8. Numerous valuable parts and materials
9. Increased business resilience
10. 25+years of experience
11. B2B eases product localization

W

1. Philips does not keep ownership of its systems
2. Collecting part evidence
3. Suppliers are monopolists
4. BOM is the leading factor for design decisions

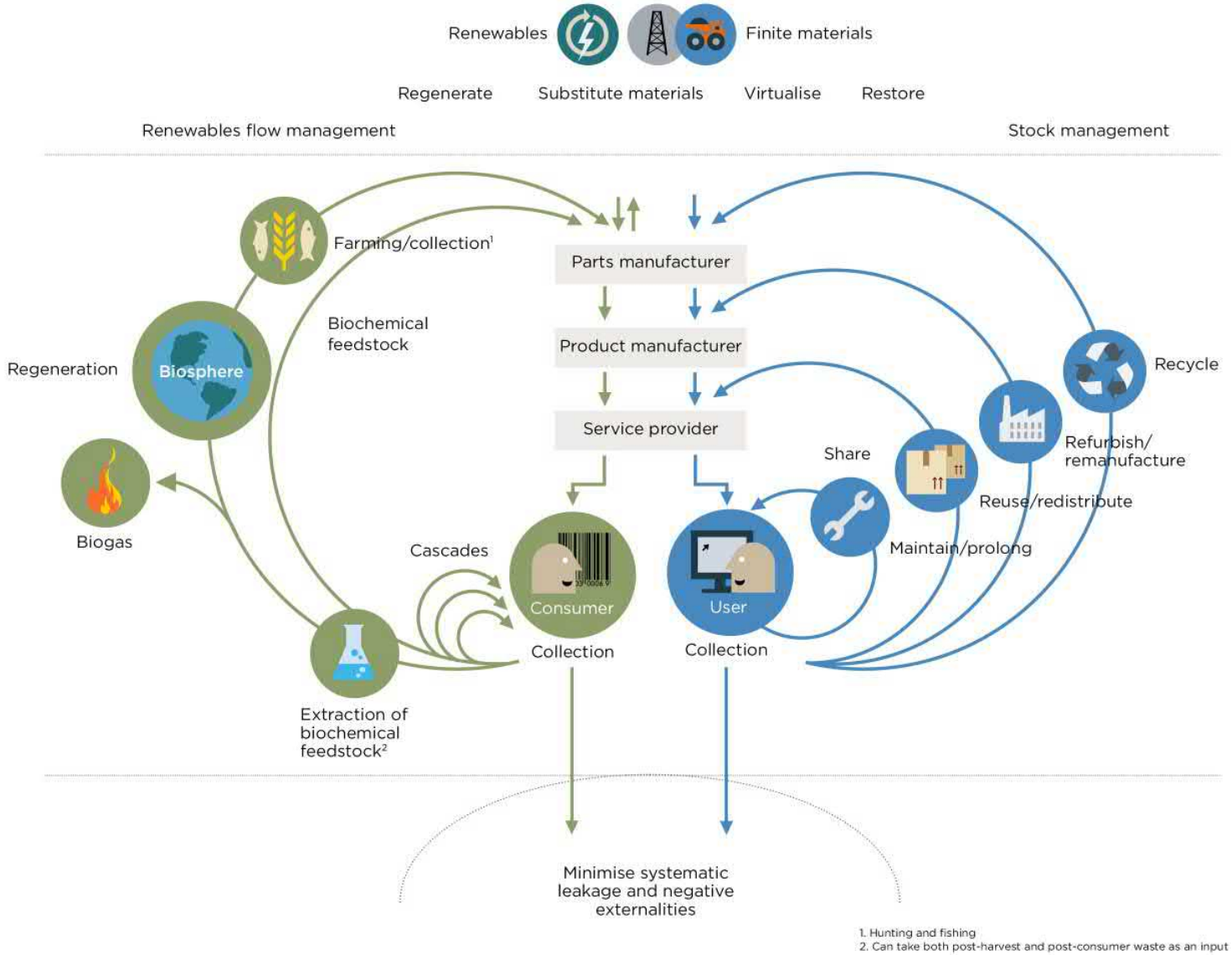
EXTERNAL FORCES

O

1. Modular design enables an intermediate upgrade of effectiveness
2. Make Design for Refurbishment a new work-flow
3. Collaboration with suppliers can help to align the design of parts with refurbishment activities
4. Return flows are required
5. The possibility for intermediate (promotional) touch-points with clients
6. More customer involvement in the customer relationship
7. Platform design opens up doors for design for refurbishment
8. Elongate the customer relationship through platform design
9. There are many opportunities for cross-functional collaboration
10. The expertise of suppliers can contribute to the development of tests to provide evidence of the remaining effective lifetime of parts
11. Trends in health care
12. Increased modularity enables parallel refurbishment activities

T

1. Brokers active in the market
2. Unstable prices of raw materials
3. Imminent legislative measures
4. Under defined terminology
5. External procurement of parts, potentially hampers refurbishment
6. A too narrow specialism of system engineers potentially causes a lack of challenge on the work floor
7. Terminology deviations amongst industries


Renewables
Finite materials
Regenerate
Substitute materials
Virtualise
Restore
Renewables flow management
Stock management
Farming/collection[1]
Parts manufacturer
Biochemical feedstock
Product manufacturer
Regeneration
Biosphere
Recycle
Service provider
Refurbish/ remanufacture
Share
Reuse/redistribute
Biogas
Cascades
Maintain/prolong
Consumer
User
Collection
Collection
Extraction of biochemical feedstock[2]
Minimise systematic leakage and negative externalities
1. Hunting and fishing
2. Can take both post-harvest and post-consumer waste as an input

Circular Product Readiness methode

CIRCULAR PRODUCT READINESS

Een uitgebreide methode specifiek gericht op **ontwerpers**. De methode is de eerste indicator methode voor het beoordelen van circulair productontwerp op een **breed scala aan ontwerpaspecten**.

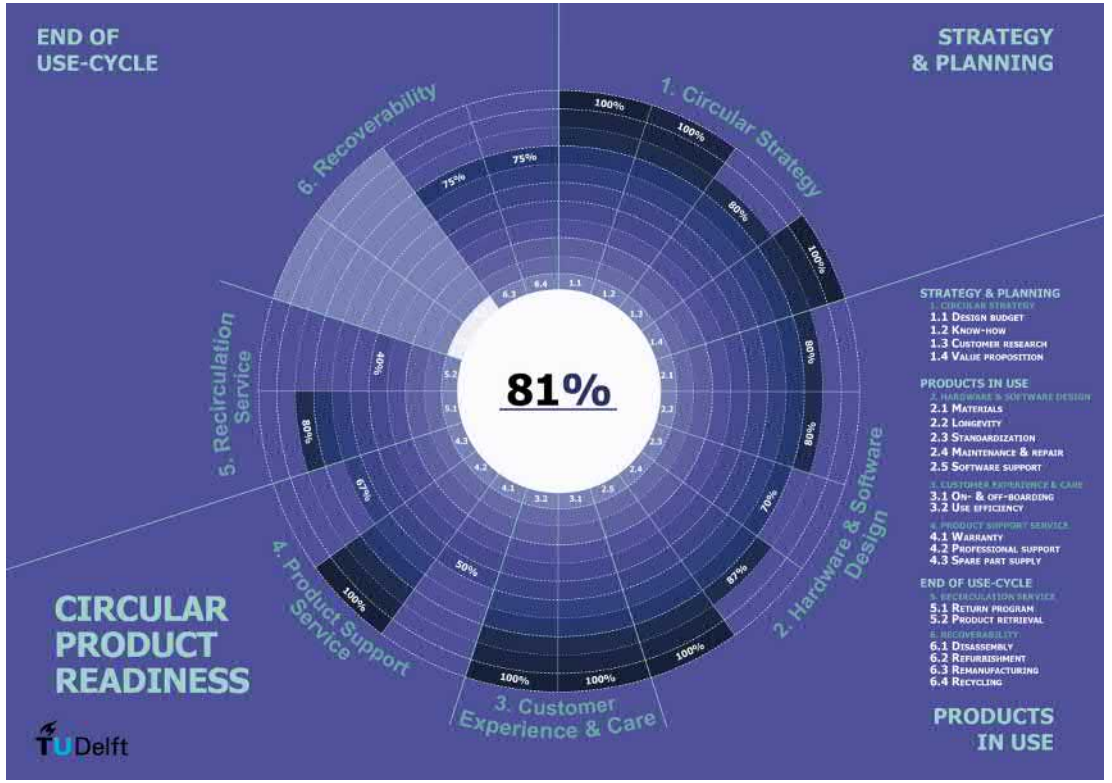
De methode maakt onderscheid tussen vier niveaus van gereedheid en toont zowel sterke punten van bedrijven als mogelijkheden voor verbetering.

De methode...

- Maakt gebruik van semantiek van productontwerp om ontwerpaspecten te evalueren

- Neemt de volledige levenscyclus in beschouwing

- Is ontwikkeld voor industrieel gebruik

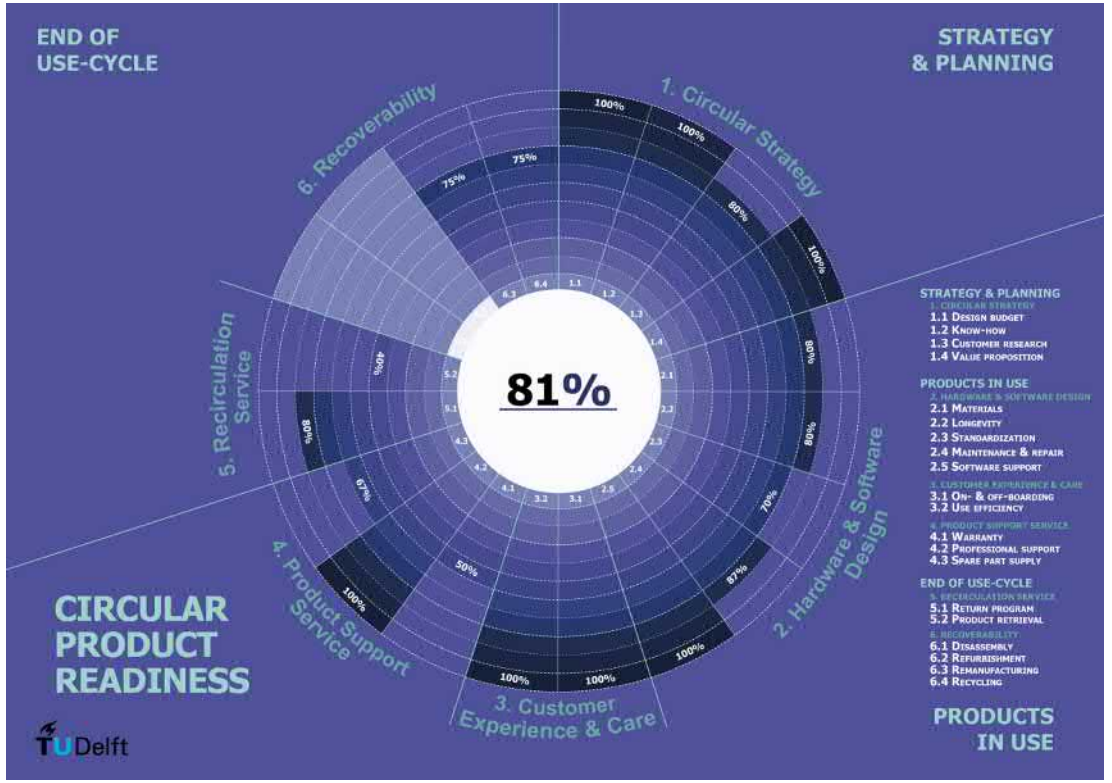


[Link to journal article]

Ontwikkeling van de methode

De ontwikkeling van de mehotde is gebaseerd op **literatuuronderzoek** en **kenniscoproductiesessies** met circulaire ontwerpexperts over onderwerpen als duurzaamheid, reparatie, remanufacturing en recycling.

De methode is geëvalueerd met **twee multinationals** die actief zijn in de witgoed- en auto-industrie.



CPR Themes and indicators

THEMES

Indicators

1. STRATEGY AND PLANNING

1.1 Budget availability for circular product design
1.2 Access to circular design expertise
1.3 Customer research attuned to needs in all use-cycles
1.4 Circular value proposition design

2. HARDWARE AND SOFTWARE DESIGN

2.1 Materials
2.2 Longevity
2.3 Standardization across the product portfolio
2.4 Maintenance & repair
2.5 Hardware supports software updates

3. CUSTOMER EXPERIENCE AND CARE

3.1 User and product on- and offboarding
3.2 Product use-efficiency

4. PRODUCT SUPPORT SERVICE

4.1 Warranty
4.2 Professional support service for maintenance, repair and upgrades
4.3 Spare part supply

5. RECIRCULATION SERVICE

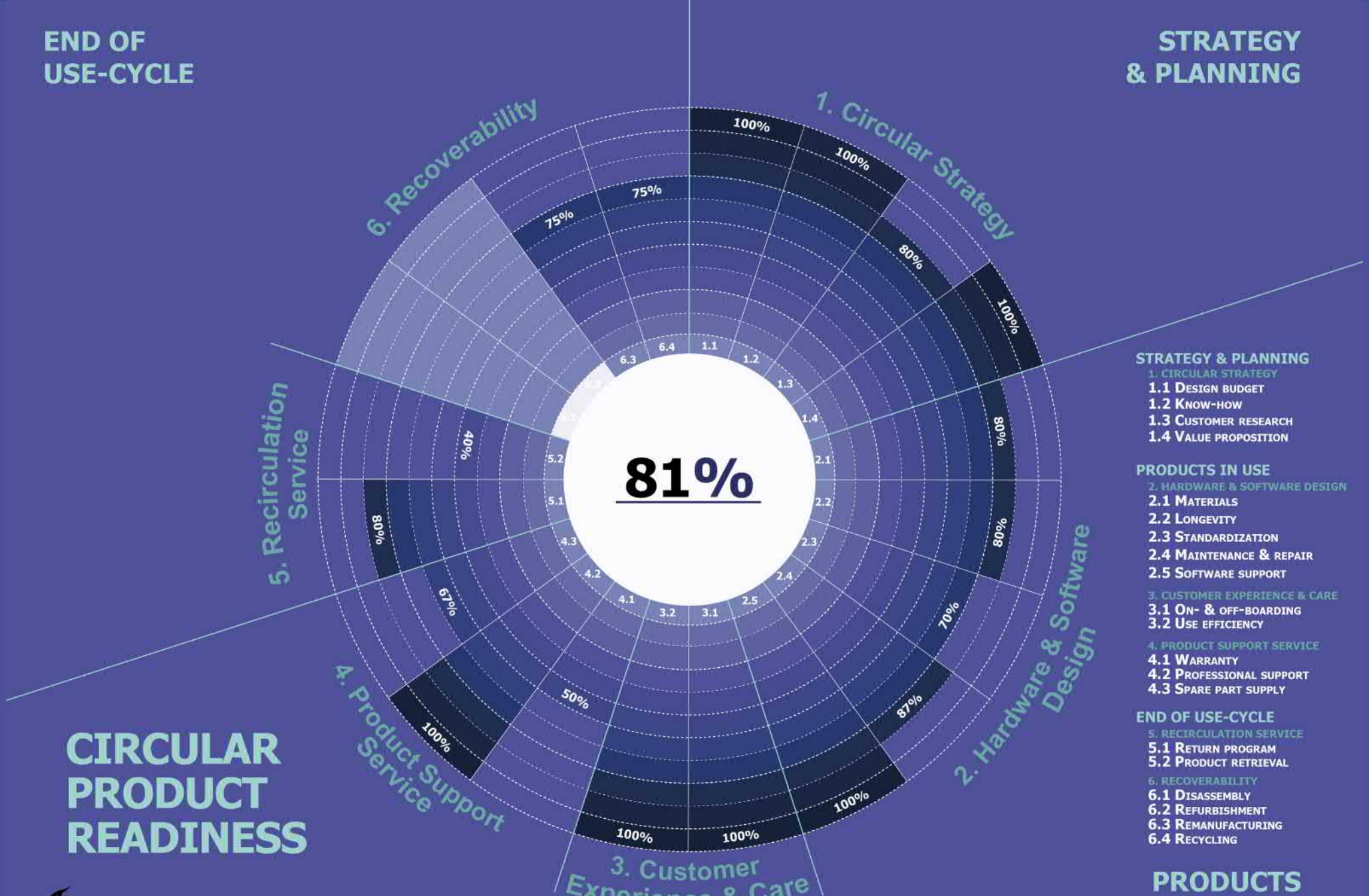
5.1 Product Return Program
5.2 Product Retrieval

6. RECOVERABILITY

6.1 Disassembly
6.2 Refurbishment
6.3 Remanufacturing
6.4 Recycling

END OF USE-CYCLE

STRATEGY & PLANNING



STRATEGY & PLANNING

1. CIRCULAR STRATEGY
- 1.1 DESIGN BUDGET
- 1.2 KNOW-HOW
- 1.3 CUSTOMER RESEARCH
- 1.4 VALUE PROPOSITION

PRODUCTS IN USE

2. HARDWARE & SOFTWARE DESIGN
- 2.1 MATERIALS
- 2.2 LONGEVITY
- 2.3 STANDARDIZATION
- 2.4 MAINTENANCE & REPAIR
- 2.5 SOFTWARE SUPPORT

3. CUSTOMER EXPERIENCE & CARE
- 3.1 ON- & OFF-BOARDING
- 3.2 USE EFFICIENCY

4. PRODUCT SUPPORT SERVICE
- 4.1 WARRANTY
- 4.2 PROFESSIONAL SUPPORT
- 4.3 SPARE PART SUPPLY

END OF USE-CYCLE

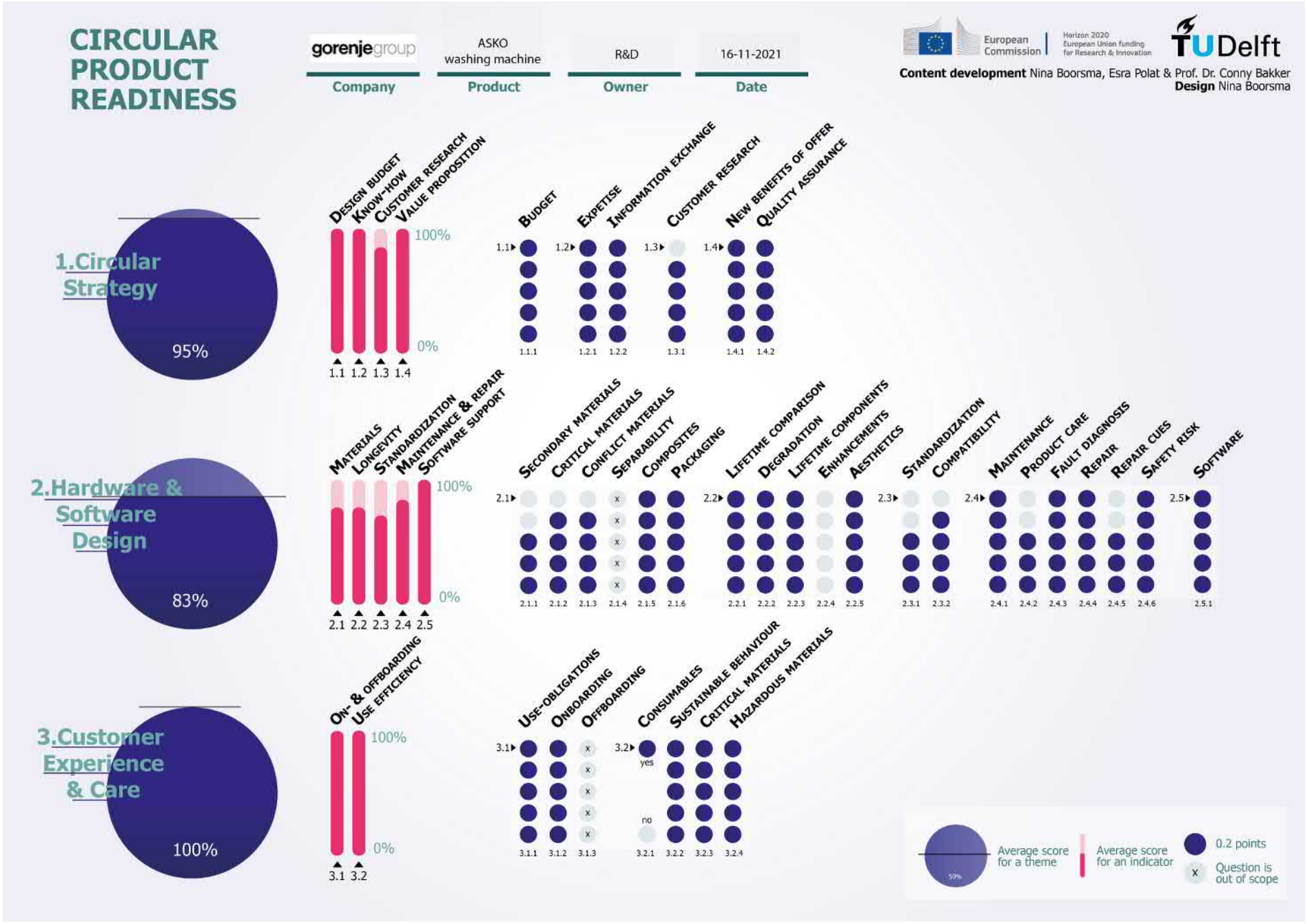
5. RECIRCULATION SERVICE
- 5.1 RETURN PROGRAM
- 5.2 PRODUCT RETRIEVAL

6. RECOVERABILITY
- 6.1 DISASSEMBLY
- 6.2 REFURBISHMENT
- 6.3 REMANUFACTURING
- 6.4 RECYCLING

CIRCULAR PRODUCT READINESS

PRODUCTS IN USE

TU Delft


CIRCULAR PRODUCT READINESS
gorenjegroup
Company
ASKO washing machine
Product
R&D
Owner
16-11-2021
Date
European Commission
Horizon 2020 European Union funding for Research & Innovation
TU Delft
Content development Nina Boorsma, Esra Polat & Prof. Dr. Conny Bakker
Design Nina Boorsma
1.Circular Strategy
95%
Design budget
Know-how
Customer research
Value proposition
100%
0%
1.1 1.2 1.3 1.4
Budget
Expetise
Information exchange
Customer research
New benefits of offer
Quality assurance
1.1 1.2 1.3 1.4
1.1.1 1.2.1 1.2.2 1.3.1 1.4.1 1.4.2
2.Hardware & Software Design
83%
Materials
Longevity
Standardization
Maintenance & repair
Software support
100%
0%
2.1 2.2 2.3 2.4 2.5
Secondary materials
Critical materials
Conflict materials
Separability
Composites
Packaging
Lifetime comparison
Degradation
Lifetime components
Enhancements
Aesthetics
Standardization
Compatibility
Maintenance
Product care
Fault diagnosis
Repair
Repair cues
Safety risk
Software
2.1 2.2 2.3 2.4 2.5
2.1.1 2.1.2 2.1.3 2.1.4 2.1.5 2.1.6 2.2.1 2.2.2 2.2.3 2.2.4 2.2.5 2.3.1 2.3.2 2.4.1 2.4.2 2.4.3 2.4.4 2.4.5 2.4.6 2.5.1
3.Customer Experience & Care
100%
On- & offboarding
Use efficiency
100%
0%
3.1 3.2
Use-obligations
Onboarding
Offboarding
Consumables
Sustainable behaviour
Critical materials
Hazardous materials
3.1 3.2
yes
no
3.1.1 3.1.2 3.1.3 3.2.1 3.2.2 3.2.3 3.2.4
Average score for a theme
Average score for an indicator
0.2 points
Question is out of scope

CPR Report

CPR Questions

CIRCULAR PRODUCT READINESS

2022

1. STRATEGY & PLANNING

1.1 BUDGET AVAILABILITY FOR CIRCULAR PRODUCT DESIGN

1.1.1 *Has your company made a budget available for circular design?*

- Yes — 1
- This is initiated — 0.8
- This is planned — 0.4
- This is not considered — 0

1.2 ACCESS TO CIRCULAR DESIGN EXPERTISE

1.2.1 *Does your company have access to circular design expertise?*

This could be circular design expertise internally or from an external party, such as advisors, consultancies, etc.

- Yes, we have access to either internal and/ or external expertise — 1
- We are in the process of acquiring (additional) expertise — 0.8
- We are planning to acquire additional expertise — 0.4
- No, we do not have access to circular design expertise — 0
- N/A — -

1.2.2 *Does your company have channels to exchange product design information with stakeholders, like repair and remanufacturing technicians?*

- Yes, we have access to either internal and/ or external expertise — 1
- We are in the process of acquiring (additional) expertise — 0.8
- We are planning to acquire additional expertise — 0.4
- No, we do not have access to circular design expertise — 0
- N/A — -

1.3 CUSTOMER RESEARCH ATTUNED TO NEEDS IN ALL USE-CYCLES

1.3.1 *To what extent are the needs of customers not only considered in the first use-cycle, but also in the subsequent use-cycles of the product?*

- This is the norm — 1
- This is initiated — 0.8
- This is planned — 0.4
- This is not considered — 0
- N/A — -

1.4 CIRCULAR VALUE PROPOSITION DESIGN

1.4.1 *Does the circular value proposition and its related service and product offer new benefits to customers?*

- Yes, there are new benefits to this circular value proposition — 1
- We are in the process of adding new benefits — 0.4
- No, there are no new benefits to this circular value proposition — 0
- N/A — -

1.4.2 *To what extent does value proposition design support high product quality not only in the first use-cycle but also in subsequent use-cycles for the products?*

- This is the norm — 1
- This is initiated — 0.8
- This is planned — 0.4
- This is not considered — 0

2. HARDWARE & SOFTWARE DESIGN

2.1 MATERIALS

2.1.1 *What fraction of the material value, by cost price, consists of recycled and/ or reused materials calculated over all use-cycles?*

This can be calculated using the following formula: (cost price of recycled and reused materials / cost price of materials in total) x 100%. For products with multiple use-cycles, the average of this fraction over the use-cycles can be calculated.

- 0% — 0
- 1 - 19% — 0.4
- 20 - 39 % — 0.6
- 40 - 69% — 0.8
- 70 - 100% — 1

2.1.2 *What amount of the material value, by cost price, consists of critical materials?*

Critical materials for product designers are defined by Peck et al. (2015) as "elements from the periodic table of elements (metals/ rare earths) that may be at risk of price volatility and supply restrictions, they are often present in small quantities in technology products, substitution usually changes a product's properties and/ or performance." Examples of common critical materials to the EU are the following: Lithium, Beryllium, Magnesium, Scandium, Chromium, Cobalt, Gallium, and Germanium (Bauer et al. 2010).

- €0 — 1
- €0 - 0,09 — 0.8
- €0,1 - 0,19 — 0.6
- €0,2 - 0,4 — 0.4
- €0,4 — 0

2.1.3 *What amount of the material value, by cost price, consists of conflict materials?*

Conflict minerals refer to raw materials or minerals that come from a particular part of the world where conflict is occurring (i.e. those specifically associated with armed conflict, human rights abuses and corruption) that affect the mining and trading of those materials (Diemer et al. 2021). Examples of common conflict materials include the 3TG: tantalum, tin, tungsten, and gold.

- €0 — 1
- €0 - 0,09 — 0.8
- €0,1 - 0,19 — 0.6
- €0,2 - 0,4 — 0.4
- €0,4 — 0

2.1.4 *Does the product contain easily separable biodegradable or compostable components?*

- The product is fully biodegradable or compostable — 1
- The product contains biodegradable and compostable components that are easy to separate — 1
- The product contains biodegradable and compostable components that are hard to separate — 0
- The product does not contain any biodegradable or compostable components — -

2.1.5 *Does the product contain composite materials that are designed to last?*

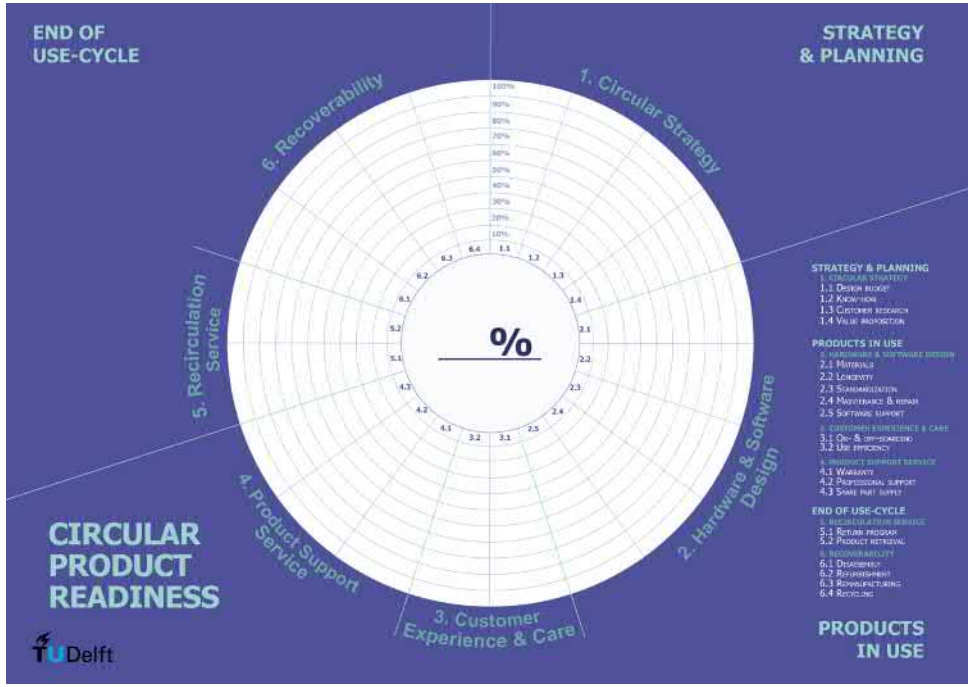
A composite material is a combination of two materials with different physical and chemical properties. Materials commonly used for composites are polymers, metals and ceramics.

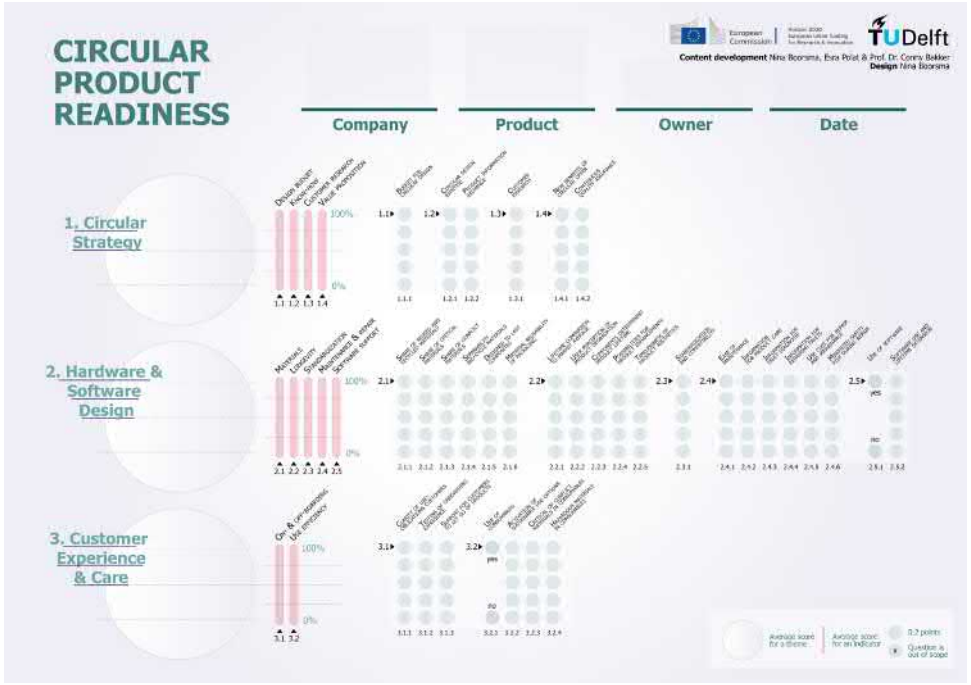
- The composite materials used in this product are recyclable — 1
- The product contains composite materials that are easy to separate and designed to last — 0.6
- The product contains composite materials that are easy to separate, but not designed to last — 0.2
- The product contains composite materials that are hard to separate — 0
- No, the product does not contain any composite materials — -

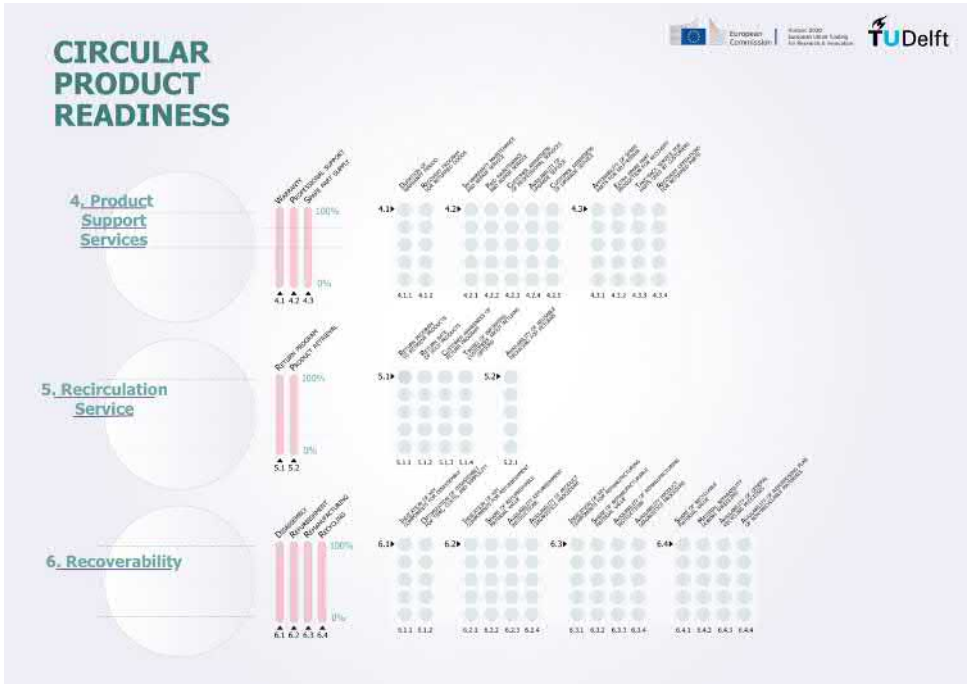
2.1.6 *Does the product packaging consist of recyclable, biodegradable, or compostable materials?*

- Yes, the packaging is fully recoverable — 1
- The packaging is partly recoverable — 0.8
- This is planned — 0.4
- The packaging is not recoverable — 0
- N/A — -

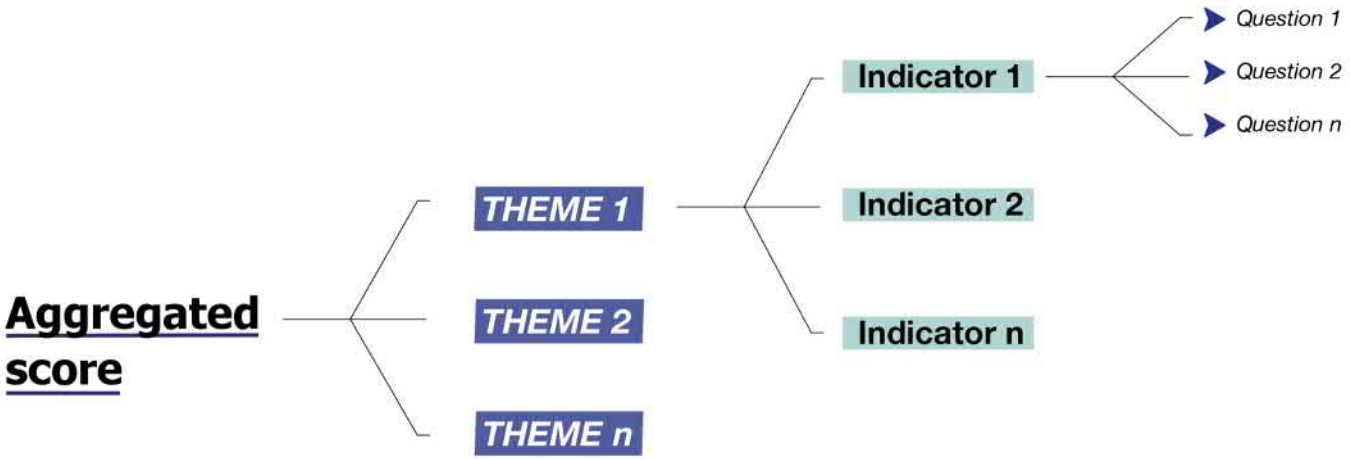
CPR Template







CPR Scoring system



Casestudy: Productieprinters

Link to dissertation

The gap

Design for Remanufacturing is uitgebreid bestudeerd, maar deze manier van ontwerpen wordt in de praktijk niet op grote schaal toegepast, hoewel bedrijven al tientallen jaren aan remanufacturing doen.

Hoofdonderzoeksvraag

Hoe kan strategisch ontwerp bijdragen aan de bredere implementatie van remanufacturing?

Hoofdonderzoeksvraag

Hoe kan strategisch ontwerp bijdragen aan de bredere implementatie van remanufacturing?

Een productieproces waarbij gebruikte producten
een gestandaardiseerd industrieel proces doorlopen en
worden hersteld tot de oorspronkelijke product specificatie.

Hoofdonderzoeksvraag

Hoe kan strategisch ontwerp bijdragen aan de bredere implementatie van remanufacturing?

Positioneert producten op de markt in relatie tot andere aanbiedingen van het bedrijf, rekening houdend met de behoeften van de markt en de langetermijndoelstellingen van het bedrijf.

Methode

Grondige casestudy

- Fabrikant van professionele productieprinters
- Lange geschiedenis in remanufacturing
- Op zoek naar manieren om Design for Remanufacturing te implementeren

Link to journal article

Methode


Product design
Strategic design
New product development
First market release
Target segments
Segment parameters
Sales pitch
Remanufacturing process
Disassembly
Cleaning & sorting
Inspection
Replacem.
Reassembly
Testing
Second market release
Target segments
Segment parameters
Sales pitch


Product design
Strategic design
New product development
Concept development
Product definition
Embodiment design
First market release
Target segments
Segment parameters
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Target segments
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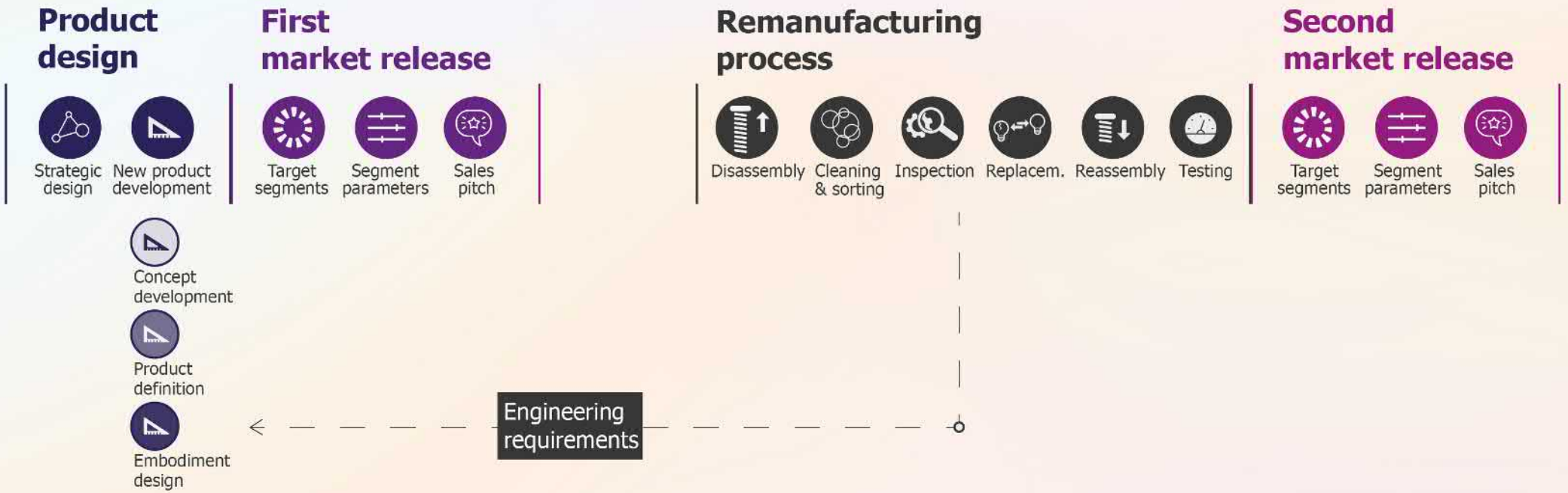
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Product design

Strategic design

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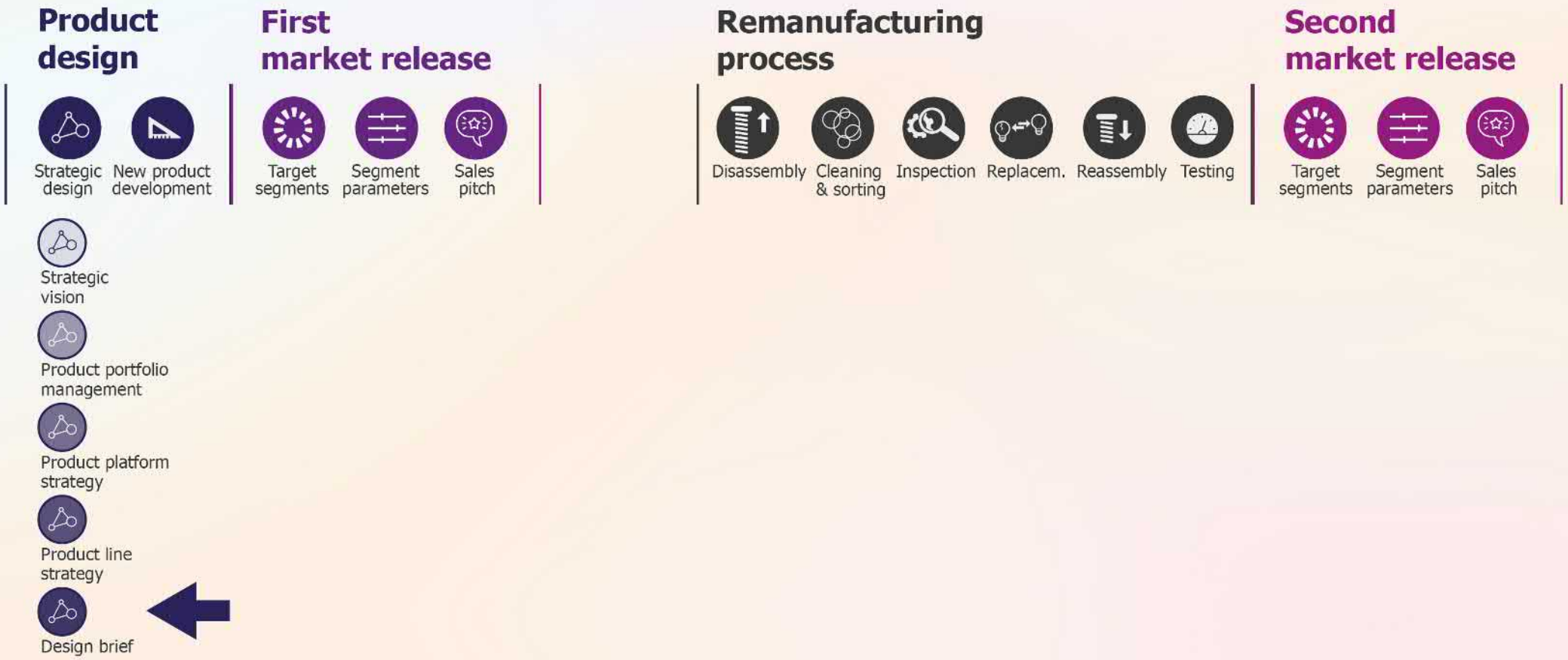
Strategic vision

Product portfolio management

Product platform strategy

Product line strategy

Design brief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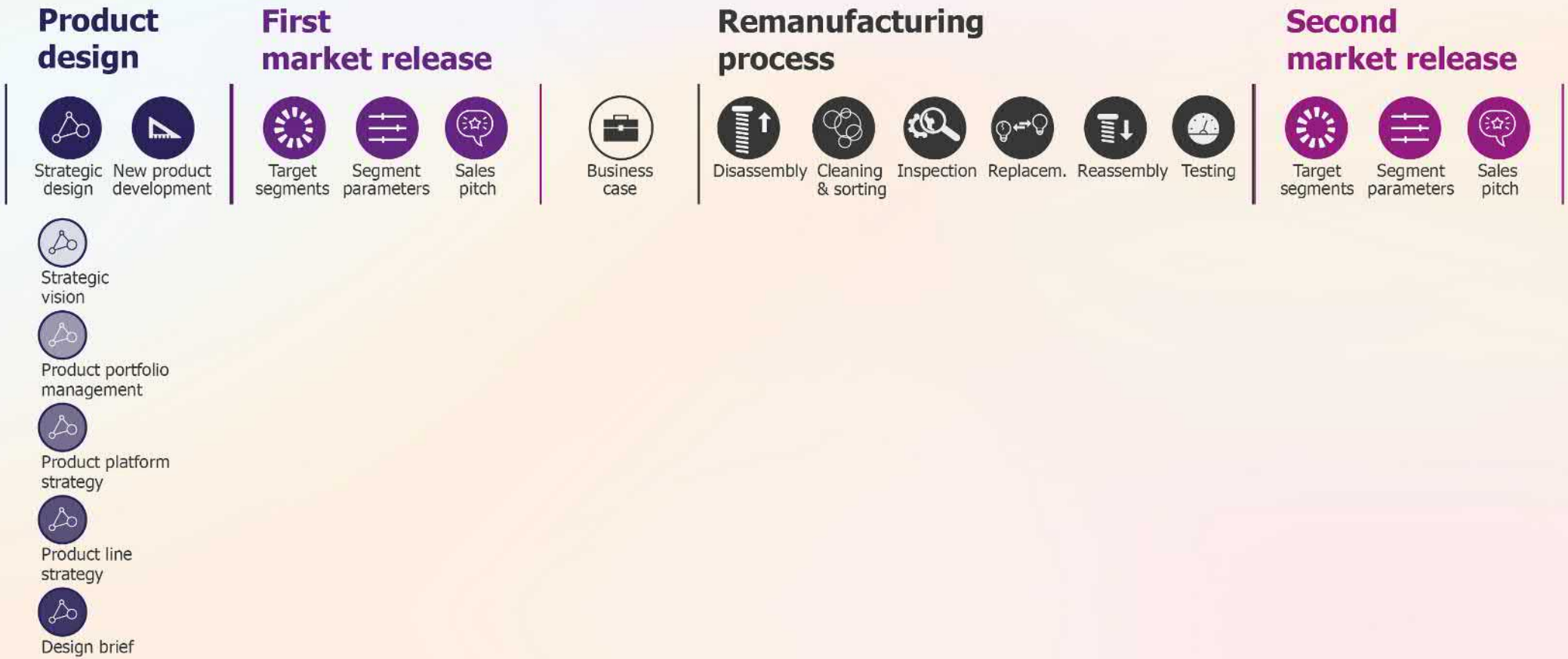
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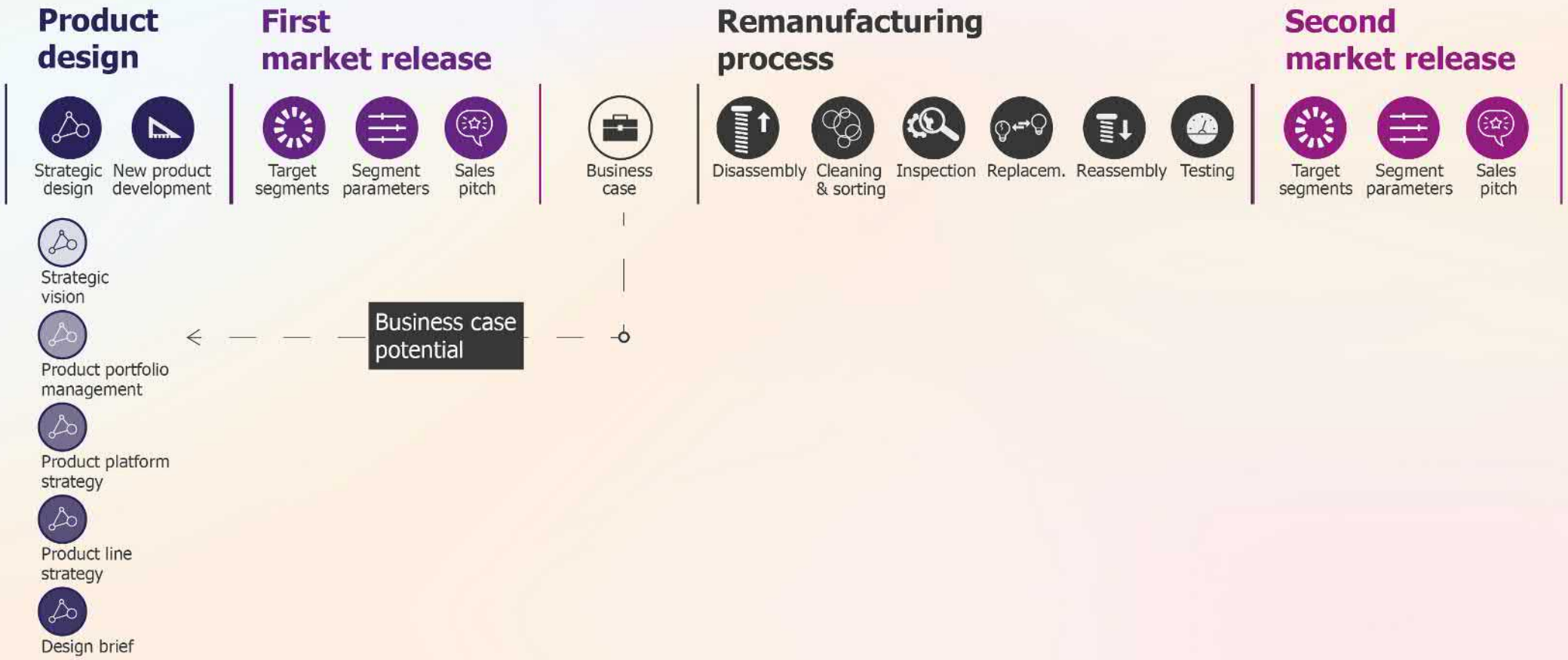
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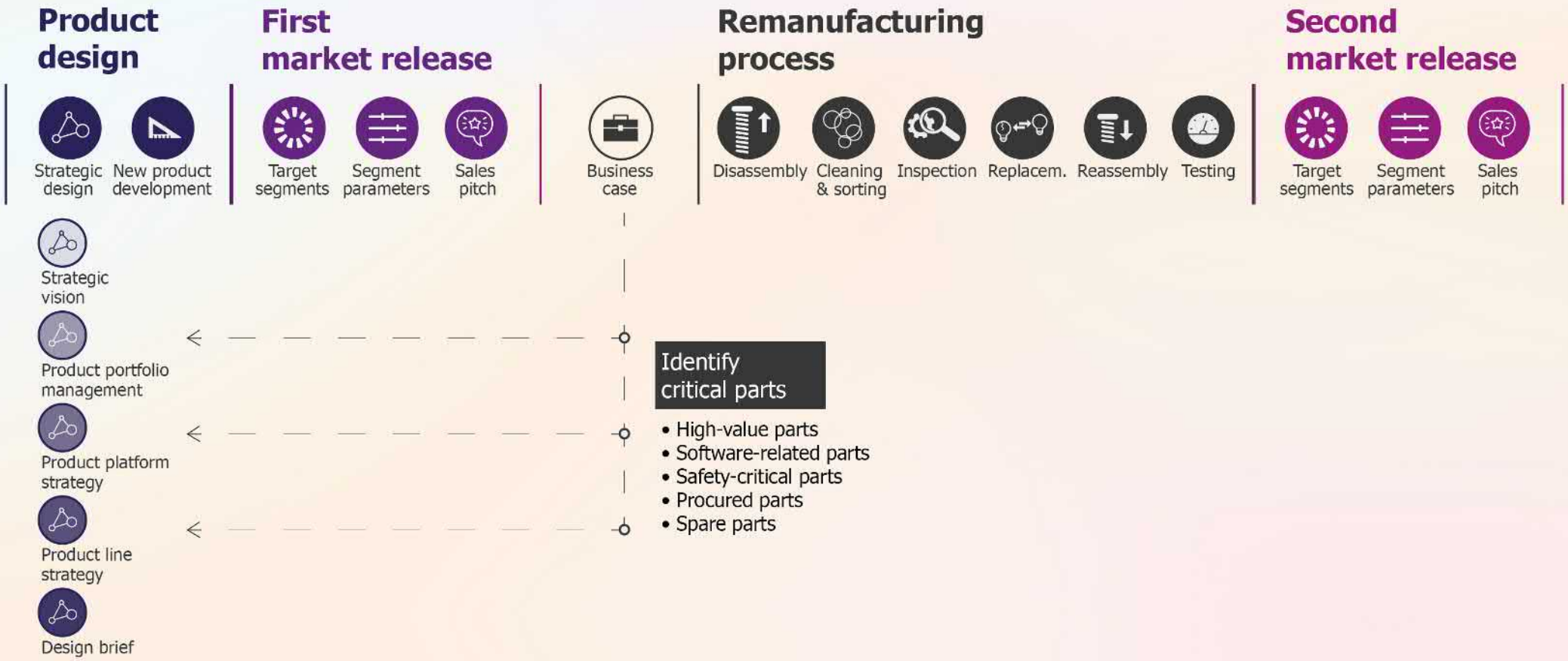
Business case potential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Design brief
Identify critical parts
• High-value parts
• Software-related parts
• Safety-critical parts
• Procured parts
• Spare parts

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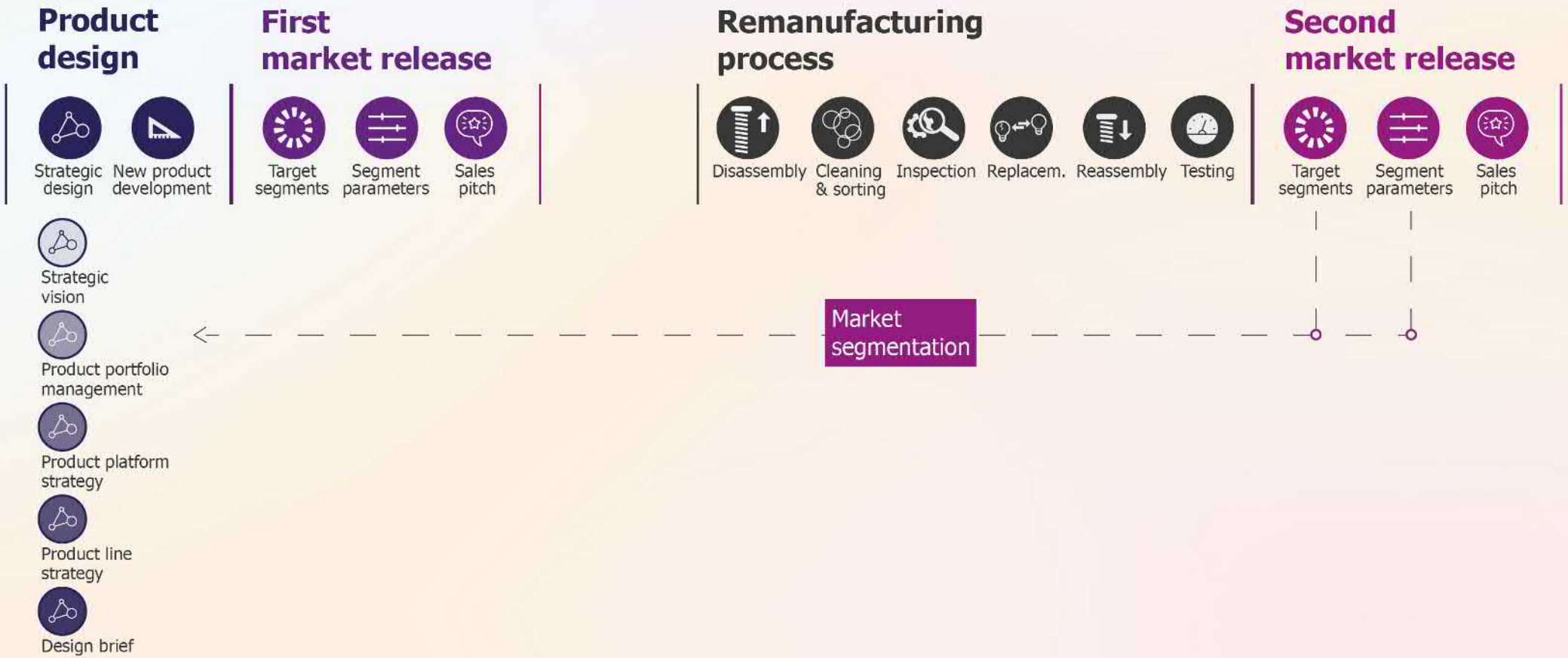
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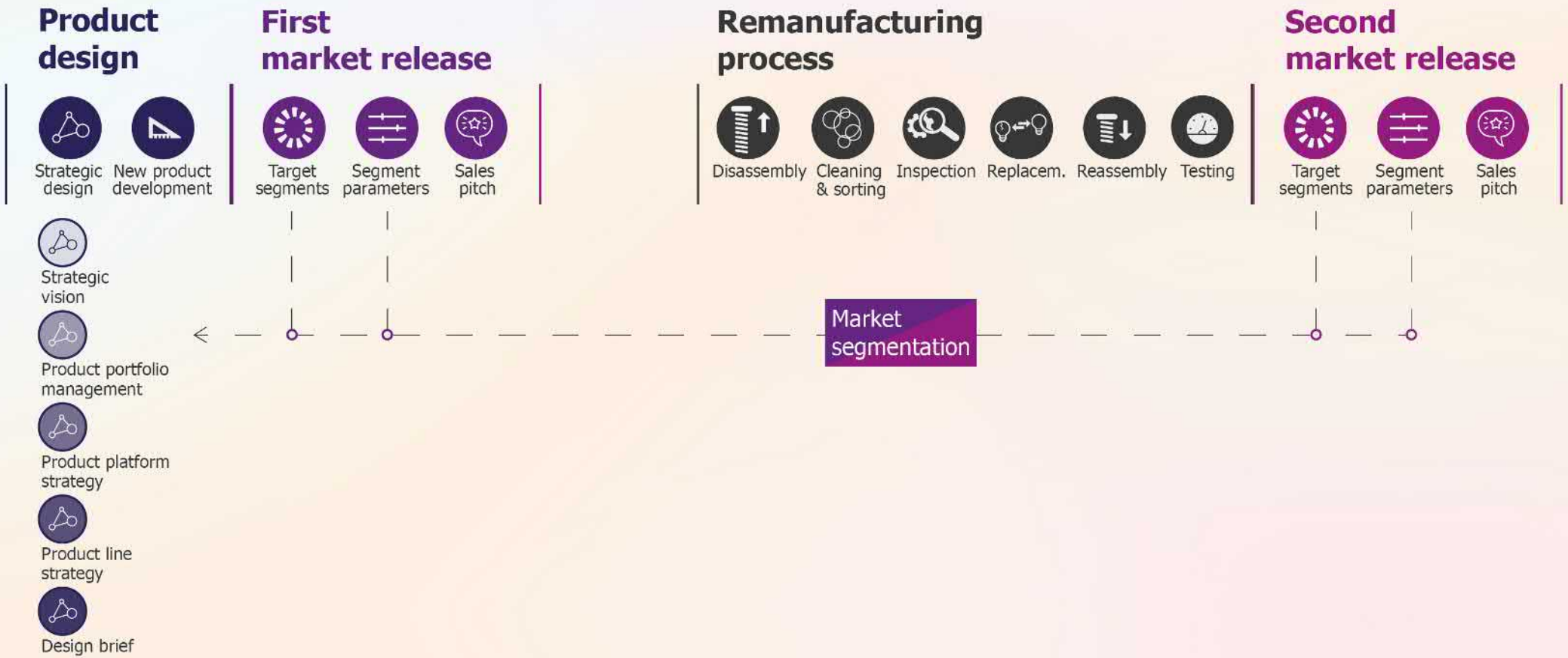
Market segmentation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Market segmentation

- Markets served with existing technology
  - → **Offer remanufactures products**
- Markets served with new technology
  - → **Offer new products**

Conclusies

We kunnen strategisch ontwerp gebruiken om remanufacturing om te vormen van van een technische benadering aan het einde van de levensduur naar een strategisch bedrijfsmiddel.

Zo kun je..

- Meer mogelijkheden voor remanufacturing vinden
- Producten in de portfolio differentiëren
- Mogelijkheden voor ontwerpstandaardisatie vinden

De Circular Product Readiness methode kan helpen om dit op een holistische manier te bereiken. Dit alles brengt ons een stap dichter bij het ontwikkelen van geïntegreerde circulaire ontwerpstrategieën.

Bedankt voor uw aandacht!