A Practical Five-Phase Guide to
Circular Medical Device Design

Heal Without Harm

Design Circular

Medical Devices

Digital Health in the Circular Economy

Colophon

Heal Without Harm; Design Circular | A practical five-step guide for designing circular medical devices

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Heal Without Harm
Design Circular
Medical Devices

Making Sustainability
a Healthcare Priority

Purpose and Application

About this guide

Climate change is a pressing challenge, and healthcare is a major contributor. In this guide MedTech developers will learn how to reduce the environmental impact of medical devices, improving resource efficiency and long-term value, while still maintaining clinical quality.

How this guide supports your work

Working through this guide enables comparison of linear and circular device lifecycles and their environmental impacts, application of circular strategies and design criteria to develop more sustainable devices, identification of key environmental hotspots for maximum impact, exploration of approaches to extend device life, and development of strategies to overcome the most common barriers.

Scope and limitations

All research used to develop this guide was conducted in Europe and the United States. As a result, the guidance reflects the regulatory frameworks, healthcare systems, and market conditions specific to these regions, and may not be directly applicable to other geographic or healthcare contexts without further adaptation.

Intended users

Professionals involved in medical device development and life cycle management who identify with at least one of the roles below.

Design & Engineering
Responsible for turning clinical needs into manufacturable and more circular medical device designs, including decisions on structure, modularity, and repairability.

Business & Strategy
Responsible for aligning circular solutions for medical devices with organisational goals, economic viability, and long-term value creation through business model and market development.

Impact & Sustainability
Responsible for assessing and reducing environmental and social impacts across the medical device life cycle using circular and sustainability assessment methods.

Regulatory & Quality
Responsible for ensuring medical devices and circular strategies comply with regulations, safety standards, and risk management requirements across the product (or device) life cycle.

Operations & Supply Chain
Responsible for managing production, logistics, procurement, and reverse flows to enable safe and efficient circulation of medical devices and materials across the lifecycle.

Clinical & End user
Provides insight into the real-world use of medical devices in clinical and home care settings, ensuring usability, effectiveness, and acceptance.

Users should identify with one or more of the six roles defined in this guide.
Each role recurs throughout the guide to ensure clear responsibility and accountability at every phase.

“More than 80% of the environmental impact of a product is determined at the development stage.”

European Commission

Healthcare aims to improve health outcomes, but the systems, products, and processes that enable care also generate substantial environmental impacts. These impacts increasingly contribute to the very health risks that healthcare seeks to prevent. In 2019, it was estimated by Health Care Without Harm that healthcare accounts for approximately 4.4% of global greenhouse gas emissions, equivalent to around 2.0 gigatons CO‡ equivalent annually. If healthcare were a country, it would rank fifth among the world’s largest emitters.

Impact of the Current Device Systems

A large part of healthcare’s footprint stems from the way healthcare products are designed and produced. Many consumables, equipment, and medical devices are developed according to a “single-use, single-life” logic, relying on resource-intensive materials and linear product journeys. As a result, 71% of healthcare emissions come from the supply chain, including the production, distribution, use, and disposal of these products.

Designing for Circularity

To improve product sustainability, circular strategies are introduced. These strategies offer opportunities to reduce emissions while maintaining clinical performance, patient safety, and regulatory compliance. By considering circularity during development, designers and engineers can influence environmental performance across the entire life cycle of a medical device.

This guide provides MedTech developers practical frameworks for applying circular thinking within the medical device development process. The following sections first introduce a five-phases approach for identifying and implementing suitable circular interventions. The guide concludes with a Circular Healthcare Flows visual that illustrates how design decisions influence product life cycles, and how the combined application of the presented approaches can help shift the current linear system toward a circular model.

Time Estimation

Working through this guide is iterative. Depending on team size and device complexity, completing all five phases may take weeks to several months.

Source: Karliner et al., 2019

Watch the Video

Circular Life Cycle Within a Healthcare System

System Perspective

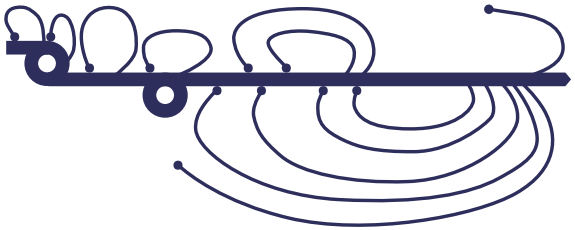
In circular design for medical devices, a system perspective is used to describe the broader circular healthcare system in which a device is developed, used, and managed over time.

This system includes clinical use environments, stakeholders across care pathways, logistics and infrastructure, material flows, and the application of circular healthcare strategies. Together, these elements define the operational context in which design decisions are made and executed.

Design choices for any phase of the product life cycle have implications across this wider system and can influence downstream outcomes.

Circular healthcare flows visual

The **Circular Healthcare Flows (CHF) visual** illustrates the circular healthcare system, including the application of circular healthcare strategies across system-level flows. It provides a system-level representation of how medical devices move through healthcare and material cycles and can deepen ideation. The visual is introduced in full on › page 52 of this guide.



Guide Structure

A Define Understand the need and set priorities page 13

Clarify why a solution is needed and whether it is justified. Assess the current environmental and social impacts of the device to identify key improvement areas and set priorities for redesign.

B Question Reframe the design challenge page 19

Examine existing assumptions, protocols, and practices behind current device models. Challenge the status quo to reframe the design problem and identify opportunities to reduce environmental impact.

C Circulate Keep the system looping page 27

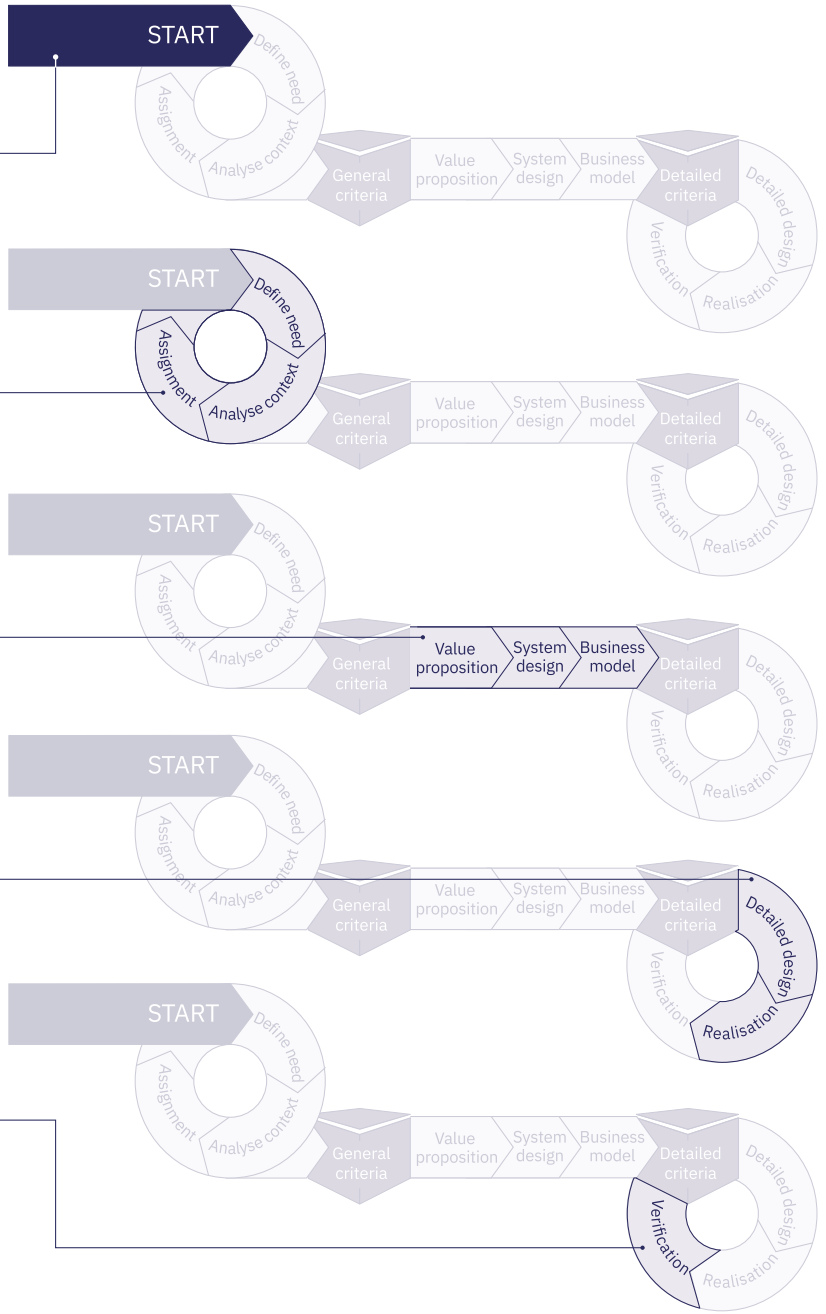
Ideate on the circular system in which the device operates. Identify relevant circular strategies to keep the device in use, enable return flows, and support recirculation.

D Embody Make devices last page 35

Translate insights into concrete design requirements. Align detailed design decisions with selected strategies to ensure circular performance in practice.

E Evaluate Determine true impacts page 41

Review and validate the concept. Check whether all phases are addressed and environmental and social improvements are achieved.



This page shows how the five phases of the guide align with a generalised medical device development process, and the point at which each phase occurs within the workflow. Each phase includes an introduction, two to four steps, and a wrap-up.

Circular Strategies per Phase

This page introduces and maps the circular strategies across each phase of the design process. Each strategy relates to a specific stage of the device life cycle and plays an essential role in creating more circular devices throughout development.

1 Refuse

The intentional act of rejecting the production, consumption, or use of a medical product, material, or procedure, particularly those that are unnecessary, unsustainable, or harmful.

2 Replace

Substituting a medical product or procedure with an alternative that serves the same purpose but significantly reduces environmental impact.

3 Rethink

Systemically enhancing the procedures surrounding product use to drive environmentally sustainable practices, such as through rethinking patient transport and telemedicine, sharing products or introducing multifunctionality.

4 Reduce

Increasing efficiency in healthcare delivery and medical manufacturing by minimising energy and resource use, avoiding unnecessary production or consumption, limiting hazardous substances, and minimising (unnecessary) procedures.

5 Maintain

Preserving the quality, function, and safety of medical products and clinical environments to ensure reliable performance, extend their lifespan, and reduce the risk of malfunctions that could lead to potential treatment failures.

6 Repair

Restoring a faulty or broken product or component to a usable state to fulfil its intended use, which typically involves corrective maintenance, ensuring that safety and performance specifications are met for an extended period of time.

7 Reuse

Repeated use of a medical device on multiple patients for the same intended purpose, after decontamination when needed, and without significant modification.

8 Refurbish

Restoring a product to good working condition through decontamination, repairs, upgrades, cosmetic changes, performance checks, reinstallation, warranty assurance, and parts replacement.

9 Remanufacture

Restoring products and components, often utilizing parts from discarded products, to achieve as-new condition through disassembly, decontamination, quality control, certification, repackaging, and redistribution.

10 Repurpose

Using discarded products or parts for different purposes than originally intended, such as in varied contexts (e.g. veterinary care procedures), purposes (e.g. different human procedures) and locations (e.g. developing countries).

11 Recycle

Transforming waste materials from used products or resources into new raw materials, either of the same or lower quality, through e.g. decontamination, shredding, and moulding.

12 Renew

Transforming waste materials, energy sources, and other substances into basic elements like carbon dioxide, water, biomass, or human tissue (for regenerative medicine) through natural processes.

Define

Understand the need and set priorities

Question

Reframe the design challenge

1 2 3 4

Circulate

Keep the system looping

5 6 7 8 9 10 11 12

Embody

Make devices last

5 6 7 8 9 10 11 12

Evaluate

Determine true impacts

Glossary page 92

DEFINE

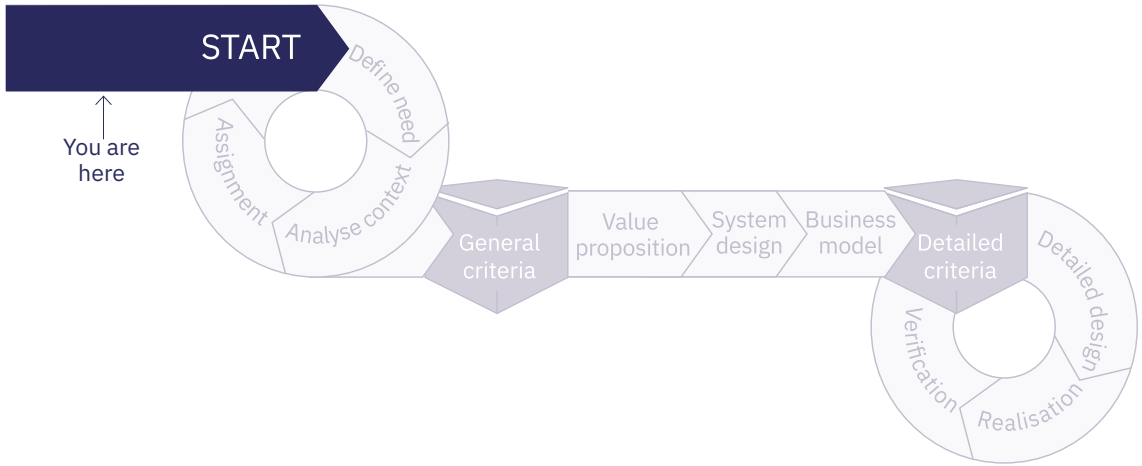
Understand the Need and Set Priorities

Before any design work begins, it is worth collecting various data to establish a clear understanding of the device, the users, the use context and the related environmental challenges.

By doing so, clinical needs, business opportunities, and key environmental hotspots of the device can be defined. Knowing these will help to align the development team, set priorities and to have a clear direction for the ideation phases that follow. In phase A, these core needs will be defined, first by defining the clinical- and then by unveiling environmental needs.

Main Responsible Roles

- Design & Engineering
- Impact & Sustainability
- Operations & SupplyChain
- Business & Strategy
- Regulatory & Quality
- Clinical & End user



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A
B
C
D
E

Define the Clinical Need

Understanding the context of use helps to uncover the actual clinical challenges and needs, which are often different from what might initially be assumed. The insights allow focus on and exploration of solutions that really fit.

Full Team Discussion

DRIDO

A

B

C

D

E

Question

1. What clinical challenges are observed in the context, and what consequences should be avoided in the future? For example, consider challenges related to quality, usability, or excessive waste.	
2. Who is directly affected now by the challenges? Who is indirectly affected, on a bigger scale?	
3. What are the underlying causes of the challenges, and which factors contribute most to their occurrence? • Technological limitations • Design limitations • Behavioural or adoption barriers • Workflow or process limitations • Other systemic factors • Training or knowledge gaps	
• Other, namely,	
4. What might be needed to solve the defined challenges?	
5. Which stakeholders will benefit directly or indirectly from fulfilling the clinical need?	

Observe & Analyse

Visit the point of use and engage directly with clinicians, patients, and other stakeholders to gain a comprehensive understanding of the device context.

Observe and analyse clinical work-flows, device interactions, user behaviours, and environmental factors to validate, refine, and expand upon the insights identified in “Question”.

Pay particular attention to how devices are handled, maintained, disposed of, and integrated into daily practice, as these observations can reveal unmet needs, operational constraints, and opportunities for improvement.

Use these observations and interactions to uncover practical challenges, verify assumptions, and identify factors that may influence the feasibility and adoption of future design solutions.

Define Environmental Needs

Alongside clinical needs, environmental needs can also be defined. By identifying the device's environmental hotspots, it is possible to determine which aspects have the greatest environmental impact. With that knowledge, the device requirements that matter most can be clearly defined, and it becomes clear where to focus when developing a circular device.

Main Responsibility

- Design & Engineering
- Operations & Supply Chain

Input

- Impact & Sustainability
- Regulatory & Quality
- Clinical & End user

Perform a Life Cycle Assessment (LCA)

Use a fast-track LCA to identify the hotspots (the largest impacts) across the full device life cycle. If LCA software or skills are not available in-house, use one of the resources below.

> Fast-Track LCA of the existing device or clinical pathway

> Carbon footprint estimation (GHG Protocol)

List of Common Environmental Hotspots

If there is no time or budget for an (fast-track) LCA, this environmental hotspot checklist can be used as a quick, rough assessment of typical environmental hotspots. However, to make evidence-based decisions rather than acting on assumptions, we strongly recommend conducting a full LCA or Fast-Track LCA to identify hotspots.

Manufacturing	• The device contains critical or rare materials (e.g. cobalt, rare earths). • The manufacturing process is energy intensive.
Transport	• Airplane transport is used for shipping. • Patients or clinicians have to travel often and/or far to use the solution.
Use	• High electricity consumption during operation. • Frequent sterilization/disinfection cycles requiring energy and water use.
End of Life	• The device contains a high number of parts/materials that are difficult to separate. • The device contains hazardous or rare materials.
Impact Amplifier	If the device is intended for single-use or is (partially) disposable, **manufacturing** and **end-of-life** impacts are amplified.

Clarify the environmental hotspot(s)

Based on your LCA select which life cycle stage(s) contributed **most** to the environmental impact:

Life cycle stage(s) with highest impact	What causes the impact within this stage?
☐ Manufacturing	
☐ Transport	
☐ Use	
☐ End of Life	

Unveil Opportunities

Main Responsibility

Design & Engineering

Operations & Supply Chain

Input

Impact & Sustainability

Regulatory & Quality

Clinical & End user

Once the clinical and/or environmental needs are identified, this part moves on to identifying improvement opportunities.

Function Tree

Using the insights from pages 12 and 13, list all functionalities needed to overcome the clinical- or environmental challenges. Explore where there may be opportunities to remove or simplify elements. Assess each functionality using the categories below.

List of Functions	Purpose	Essential	Optional
		☐	☐
		☐	☐
		☐	☐
		☐	☐

Benchmark

Review solutions which serve a similar need or solve the identified challenge already. Assess how they differ. Use these insights to identify opportunities for improvement in your own design.

Solution reviewed	How it addresses the need	Opportunities for improvement

Business
Use the opportunities identified in this page and determine in the Wrap-Up on the next page where the greatest economic value can be gained, highlighting the most promising business opportunities.

Wrap Up A

Main Responsibility

Business & Strategy

Based on full team input

Phase A allowed the identification of the clinical and environmental needs. Use this page to synthesis the key findings from Phase A. Use these findings during the ideation in Phase B.

Defined Needs

What is the identified reason or need for developing a new device? What should be achieved to make the new device successful? What are opportunities to improve the device, without compromising [clinical, business, environmental priorities]?

Define Priorities

Using the insights from Phase A, identify the top clinical-, sustainable- and business priorities for developing your device. These will be used as evaluation criteria in Phase E. If you identified additional priorities, be sure to capture them as well and record them for later reference.

Clinical priorities	Sustainable priorities	Business priorities
1.	1.	1.
2.	2.	2.
3.	3.	3.

Proceed to the next Phase

Once the team has aligned priorities and initial opportunities, the process moves into Phase B. In this phase, ideation is driven through the first four circular design strategies, identifying which improvement.

QUESTION

Reframe the Design Challenge

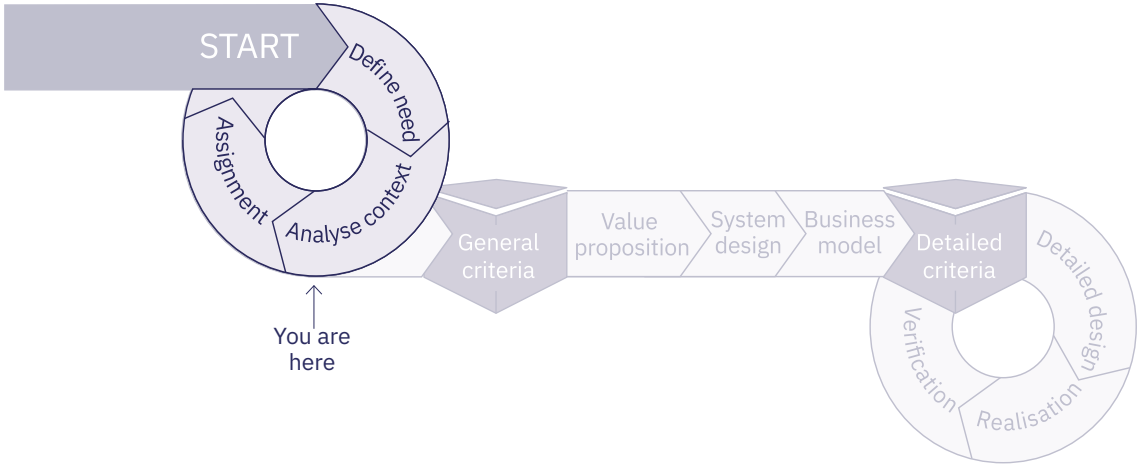
Generate ideas to solve the problem statement you defined in Phase A, starting with the highest-priority circular strategies. By applying the circular strategies refuse, replace, rethink, and reduce, unnecessary complexity and resource use can be identified and eliminated.

Main Responsible Roles

- Design & Engineering
- Impact & Sustainability
- Operations & SupplyChain
- Business & Strategy
- Regulatory & Quality
- Clinical & End user

Which circular strategies are involved in this phase?

1 Refuse 2 Replace 3 Rethink 4 Reduce



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Ideation Refuse[1]

Ideate on the Refuse strategy by exploring alternative systems, processes, and non-device approaches alongside device development helps avoid unnecessary products, reduce resource use, and support more sustainable outcomes.

Full Team Discussion

Valuable refuse examples

The examples listed show that some beyond-device solutions already solve identified problems while also adding business value. Then, a device may be unnecessary.

Examples of identified problems	Addressing the problem	Business value potential
Behavioural or adherence issue	Coaching or behaviour-change programme	Generates recurring subscription revenue with a lower cost of goods sold than hardware, and is digitally scalable.
Workflow or process inefficiency	Process redesign or implementation consulting	Generates services revenue and repositions your organisation as a solutions partner rather than a vendor, creating stronger customer retention and reducing the likelihood of switching to a competitor.
Knowledge or capability gap	Training, certification, decision support	Generates licensing or content revenue, scales digitally, and requires low initial investment.
System or coordination issue	Pathway redesign, integration, platform	Platform and data assets, supports long-term contracts, and creates opportunities for ecosystem lock-in.

REFUSE EXAMPLE 1
Refuse UV-light oral hygiene interventions, as they reduce microbes without proven impact on oral health outcomes.

REFUSE EXAMPLE 2
Refuse bloodletting procedures in cupping therapy, as there's insufficient evidence of therapeutic benefit.

Detailed examples on page 56 and 57

Choose your Strongest Idea(s)

Review the ideas generated above and select the strongest option(s) to take forward.

1. **Pursue beyond-device:** The idea clearly outperforms introducing a device and reduces environmental impact. Pursue the beyond-device idea and proceed directly to Phase E for evaluation.
2. **Develop, retain beyond-device idea:** The beyond-device idea is promising, but the exploration of a physical device remains relevant, or the environmental benefits are unclear. Go to Phase A (if not already completed), otherwise retain the beyond-device idea for evaluation in Phase E and continue with device development.
3. **Develop:** No beyond-device idea was identified. Go to Phase A (if not already completed), otherwise continue with device development as the focus.

Brainstorm Beyond-Device Opportunities

Could the need be addressed without introducing a device?

Consider whether behaviour change, process optimisation, education, system redesign, or contextual change could effectively reduce or resolve the problem before committing to a physical device.

Generate about 10 ideas to address the clinical need without the need of a physical device. At this stage, set feasibility aside and explore broadly.

Capture your most promising Refuse ideas in the Phase B wrap-up on page 22.

Ideation Replace 2

Replace explores whether the same clinical need can be fulfilled using already existing medical products or services, within the given clinical context, that deliver equivalent outcomes while significantly reducing environmental impact and maintaining clinical and business value.

Main Responsibility

- Design & Engineering
- Operations & Supply Chain

Input

- Impact & Sustainability
- Regulatory & Quality
- Clinical & End user

Brainstorm Existing Alternatives

Could the same clinical purpose be met using existing alternatives with lower environmental impact?

Focusing on substitution options within the existing market and clinical practice, consider whether currently available medical devices, procedures or services already achieve the same clinical outcome before developing a new solution. If an existing solution is identified, consider how it could be further improved to better solve the problem, increase its business value, and reduce its environmental impact based on the hotspots defined in Phase A.

Existing solutions identified?

Generate ideas to improve existing solutions that address the identified problem or fulfil the clinical need.

No existing solutions identified?

Explore how existing products or procedures could be adapted to address the identified clinical need.

REPLACE EXAMPLE 1
Replace the need for a new ventilator by improving settings on existing devices to protect premature infants.

REPLACE EXAMPLE 2
Replace electronic blood pressure monitoring with manual measurement when reliability is comparable.

> Detailed examples on page 58 and 59

TIP

Ways to minimise impact:

- **Minimise waste generation**
- **Extend product lifetime**
- **Increase number of use cycles**

Choose your Strongest Idea(s)

Review the generated ideas and select the strongest option(s) to take forward:

1. **Develop new:** No existing or adaptable solution was identified. Continue developing a new device by following the next steps.
2. **Change current:** An existing solution was found or adapted to meet the clinical need. Use it as a baseline and focus on reducing its environmental impact further by following the next steps.

In both cases, the environmental improvement achieved becomes a key business value priority carried forward throughout the design process.

Capture your most promising replace ideas in the Phase B wrap-up on > page 22.

Ideation Rethink 3

This step examines how device use can be rethought to improve system-level efficiency and sustainability, including through shared use, multifunctionality, and redesigned care delivery (e.g. telemedicine and patient flow). The guiding questions support ideation.

Main Responsibility

- Design & Engineering
- Operations & Supply Chain

Input

- Impact & Sustainability
- Regulatory & Quality
- Clinical & End user

Guiding question 1

Multifunctionality

How could functionalities be combined?

Based on the context analysis try to find possibilities to combine the function with another function in just one device.

Ideas for multifunctionality:

Good example

Rethink respiratory care by integrating oxygen delivery and pulse oximetry into one device.

Example of Good Intentions - Bad Consequences

Overlooking system
Combined ECG and SpO2 reduces disposables but increases cleaning burden and overall impact.

> Detailed examples on page 60 and 61

Guiding question 2

Standardisation

How could we enable standardisation between systems?

Find design opportunities to allow interoperability between the solution and other systems.

Ideas for standardisation:

Good example

Rethink ultrasound imaging by using a probe that can attach to any hospital monitor or standard iPad.

Example of Good Intentions - Bad Consequences

System fragility
Standardizing a patient monitor may increase upgrade need and compatibility issues.

> Detailed examples on page 62 and 63

Guiding question 3

Device Sharing

In which ways could the device be shared?

Explore how this device could be shared across different departments or users, or even different hospitals.

Ideas for device sharing:

Good example

Rethink clinical ventilator by designing them to serve multiple patients at once, reducing the number of devices needed.

Example of Good Intentions - Bad Consequences

Logistic burden
Portable infusion pump sharing increases impact through transport and cleaning need.

> Detailed examples on page 64 and 65

Capture your most promising rethink 3 ideas in the Phase B wrap-up on > page 22.

Ideation Reduce ④

Main Responsibility

Design & Engineering

Operations & Supply Chain

Input

Impact & Sustainability

Regulatory & Quality

Clinical & End user

Reduce explores whether the same clinical need can be fulfilled by reducing the resources, materials, or impacts associated with existing medical products or services, within the given clinical context, while maintaining equivalent outcomes and preserving clinical and business value.

Device Complexity

Identify opportunities to **simplify the device** without compromising its function.

Ideas for reducing device complexity:

Good example

Reduce complexity of automated insulin pump by removing seldom-used features.

Example of Good Intentions - Bad Consequences

Overcomplexity
Reusable cataract tool tips are sterilized, while a disposable tip is more sustainable.

› Detailed examples on page 66 and 67

Material Use

Find out how to **safely reduce** the amount of components or materials.

Ideas for reducing number of components and materials:

Good example

Reduce material use in smart pillboxes; eliminate unneeded interior padding and multi-player packaging.

Example of Good Intentions - Bad Consequences

Illusory safety
Safety gloves may appear safer for certain tasks, but can increase waste when hand disinfection is equally effective.

› Detailed examples on page 68 and 69

Needed Resources

Minimise the amount of **energy**, **water**, or **chemicals used** to manufacture or use the device, without affecting safety.

Ideas for reducing needed resources:

Good example

Reduce water use in endoscope cleaning by limiting it to the amount actually required.

Example of Good Intentions - Bad Consequences

Procedural habit
Opening full instrument sets ensures preparedness, but increases waste when only a few instruments are needed.

› Detailed examples on page 70 and 71

When progress stalls, revisit your assumptions. What appears infeasible may be driven by untested assumptions, overly narrow problem framing, or unnecessary constraints. Review relevant literature, standards, clinical practice, and comparable technologies to identify alternative pathways and proven approaches.

Capture your most promising reduce ④ ideas in the Phase B wrap-up on › page 22.

By exploring the circular strategies Refuse, Replace, Rethink, and Reduce, assumptions have been challenged and more sustainable directions identified. Document the strongest ideas from each strategy. For each idea, describe it and note the anticipated sustainability improvement it could deliver.

Main Responsibility

- Design & Engineering
- Operations & Supply Chain

Input

- Impact & Sustainability
- Regulatory & Quality
- Clinical & End user

1 Refuse

Beyond-device opportunities

Ideas from page 18

Anticipated sustainability improvement per idea

2 Replace

Using existing alternative medical devices, procedures or services

Ideas from page 19

Anticipated sustainability improvement per idea

3 Rethink

System-level efficiency and sustainability

Ideas from page 20

Anticipated sustainability improvement per idea

4 Reduce

Complexity, material use, and resources

Ideas from page 21

Anticipated sustainability improvement per idea

Wrap Up B

Identify which ideas from all your Phase B brainstorms complement each other and combine them into at least three concept directions. For each concept, document the strategies combined, the anticipated sustainability improvement, and any early prototype notes. Take this summary forward into Phase C.

Main Responsibility

- Design & Engineering
- Operations & Supply Chain

Input

- Impact & Sustainability
- Regulatory & Quality
- Clinical & End user

Concept 1 description

Anticipated sustainability improvement	Clinical benefits	Business benefits

Concept 2 description

Anticipated sustainability improvement	Clinical benefits	Business benefits

Concept 3 description

Anticipated sustainability improvement	Clinical benefits	Business benefits

Further iteration required? Refine your concepts and revisit this phase as needed.

CIRCULATE

Keep the System Looping

The goal of Phase C is to define post-use pathways for a device and how to design the system to enable circularity. Device design will be done in Phase D. Most devices are currently discarded and incinerated, despite retaining value and consisting of scarce resources. To support circularity, the device must be compatible with recirculation within the circular healthcare system (see Circular Healthcare Flows visual on page 52). In this phase, suitable circular strategies are identified and translated into system and collection design decisions that enable their implementation.

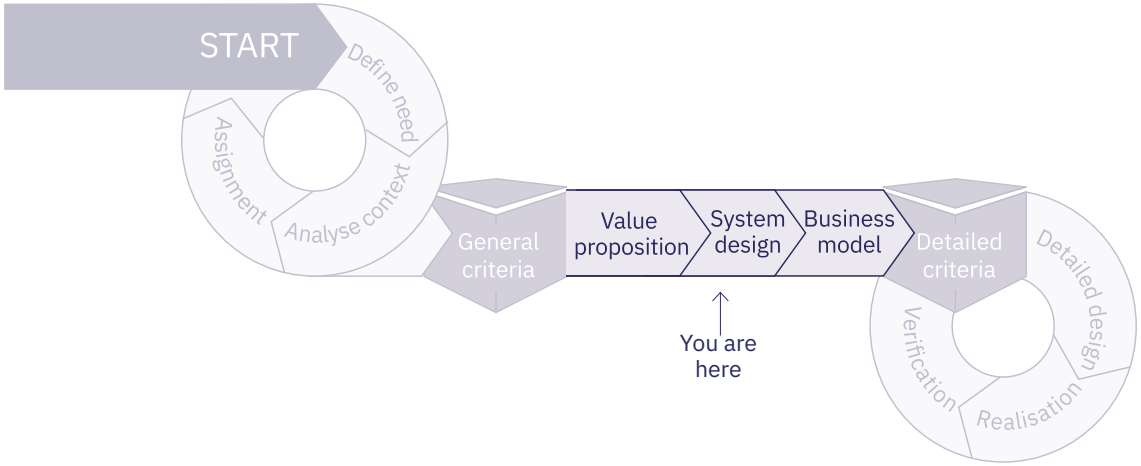
Main Responsible Roles

- Design & Engineering
- Impact & Sustainability
- Operations & SupplyChain
- Business & Strategy
- Regulatory & Quality
- Clinical & End user

Which circular strategies are involved in this phase?

All strategies aimed at extending the lifespan of a product or its components, as well as strategies aimed at recovering raw materials. The circular strategies are:

5 Maintain · 6 Repair · 7 Reuse · 8 Refurbish · 9 Remanufacture · 10 Repurpose · 11 Recycle · 12 Renew



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Determine Circular Strategies
(for Low-Criticality Devices)

This decision tree supports selection of circular strategies for **low-criticality devices**. It categorises devices by MDR class, duration of use, and expected size and cost, mapping them to commonly applied strategies. Use as a starting point for exploring relevant strategies for your design concept. If high criticality, continue to next page.

Main Responsibility
Impact & Sustainability
Regulatory & Quality

Input
Business & Strategy

Question I
What is the **criticality level** of your device?

Low Criticality (MDR class I & IIa)

High Criticality (MDR class IIb & III)
→ **go to next page** > page 27

Question II
Is the device **used in sessions or continuously** during a treatment period?

Session-based use (minutes–hours; discrete interaction, then removed)

Continuous use (used continuously during treatment; hours–days+)

Question III
Is your device **low-cost** or **high-cost**? If uncertain, use size as a proxy.

Low-cost device (consumable or *small* device) → €

High-cost device (capital or *large-scale* device) → €€

Low-cost device (consumable or *small* device) → €

High-cost device (capital or *large-scale* device) → €€

LOW-CRITICALITY DEVICE TYPES

Session-based use consumable (e.g. paper ECG electrodes)

maintain | repair | **reuse** | refurbish | remanufacture | **repurpose** | **recycle** | **renew**

Low-cost session-based use devices typically do not justify repair or remanufacturing and are primarily directed towards reuse where safe, or material recovery and repurposing at end-of-life.

Session-based use capital equipment (e.g. ultrasound machine)

maintain | **repair** | **reuse** | **refurbish** | remanufacture | **repurpose** | **recycle** | renew

High-cost session-based use devices favour repair, reuse, and refurbishment to extend life cycle. Remanufacturing or renewal is typically not applied due to device complexity and intermitent use.

Continuous use consumable (e.g. skin temperature patch)

maintain | repair | **reuse** | refurbish | remanufacture | **repurpose** | **recycle** | **renew**

Low-cost continuous-use devices favour maintenance, reuse, and recycling. Repair, refurbishment, and remanufacturing are unlikely due to low value; renewal is limited by material selection.

Continuous use capital equipment (e.g. hospital patient bed)

maintain | **repair** | **reuse** | **refurbish** | remanufacture | **repurpose** | **recycle** | renew

High-cost continuous-use devices favour maintenance, repair, reuse, and refurbishment. Remanufacturing is used selectively where value and recovery potential justify higher intervention.

CIRCULAR STRATEGIES TO IDEATE
These strategies are frequently applied for this type of device and are recommended as starting points for further exploration, while recognising that the optimal choice may differ per specific design idea.

X **Likely** suitable for device type
X **Might be** suitable for device type
X **Unlikely** to be suitable for device type

> More detailed explanation of the examples on page 72 to 75

Criticality level of an early-stage design concept:
Determine criticality based on estimated MDR classification from intended use.
Use a best-available estimate; later design changes are not expected to significantly affect this step.

In the next step, the strategies will be translated into concrete design decisions.

Determine Circular Strategies
(for High-Criticality Devices

This decision tree supports selection of circular strategies for **high-criticality devices.** It categorises devices by MDR class, duration of use, and expected size and cost, mapping them to commonly applied strategies. Use as a starting point for exploring relevant strategies for your design concept. If low criticality, return to previous page.

Main Responsibility
Impact & Sustainability
Regulatory & Quality

Input
Business & Strategy

Question I
What is the **criticality level** of your device?

Question II
What is the intended use **pattern during a treatment** period?

Question III
Is your device **low-cost or high-cost?** If uncertain, use size as a proxy.

High Criticality (MDR class IIb & III)

- **Session-based use** (minutes–hours; discrete interaction, then removed)
  - **Low-cost device** (consumable or *small* device) — € → **Session-based use consumable** (e.g. surgical stapler)
  - **High-cost device** (capital or *large-scale* device) — €€ → **Session-based use capital equipment** (e.g. lung-heart machine)
- **Continuous use** (used continuously during treatment; hours–days+)
  - **Low-cost device** (consumable or *small* device) — € → **Continuous use consumable** (e.g. EEG cup electrodes)
  - **High-cost device** (capital or *large-scale* device) — €€ → **Continuous use capital equipment** (e.g. mechanical ventilator)

Low Criticality (MDR class I & IIa)
→ **go to previous page** > page 26

HIGH-CRITICALITY DEVICE TYPES

CIRCULAR STRATEGIES TO IDEATE
These strategies are frequently applied for this type of device and are recommended as starting points for further exploration, while recognising that the optimal choice may differ per specific design idea.

Session-based use consumable (e.g. surgical stapler)

maintain | repair | **reuse** | refurbish | remanufacture | **repurpose** | **recycle** | **renew**

Low-cost session-based use devices typically do not justify repair or remanufacturing and are primarily directed towards reuse where safe, or material recovery and repurposing at end-of-life.

Session-based use capital equipment (e.g. lung-heart machine)

maintain | **repair** | **reuse** | **refurbish** | remanufacture | **repurpose** | **recycle** | renew

High-cost session-based use devices favour repair, reuse, and refurbishment to extend life cycle. Remanufacturing or renewal is typically not applied due to device complexity and intermittent use.

Continuous use consumable (e.g. EEG cup electrodes)

maintain | repair | **reuse** | refurbish | remanufacture | **repurpose** | **recycle** | renew

Low-cost continuous-use devices favour maintenance, reuse, and recycling. Repair, refurbishment, and remanufacturing are unlikely due to low value; renewal is limited by material selection.

Continuous use capital equipment (e.g. mechanical ventilator)

maintain | **repair** | **reuse** | **refurbish** | remanufacture | **repurpose** | **recycle** | renew

High-cost continuous-use devices favour maintenance, repair, reuse, and refurbishment. Remanufacturing is used selectively where value and recovery potential justify higher intervention.

X **Likely** suitable for device type
X **Might be** suitable for device type
X **Unlikely** to be suitable for device type

> More detailed explanation of the examples on page 76 to 79

Criticality level of an early-stage design concept:
Determine criticality based on estimated MDR classification from intended use.
Use a best-available estimate; later design changes are not expected to significantly affect this step.

In the next step, the strategies will be translated into concrete design decisions.

System Design Ideas

Main Responsibility

Operations & Supply Chain

Based on full team input

Select the circular strategies defined in Phase C pages 26-27 and generate ideas to apply these for each concept of Phase B. Use the system design considerations to guide your thinking, but do not focus on embodiment design yet. This will follow in Phase D.

	Ideas	System Design Considerations
☐ Maintain		traceability, workflow fit, regulations
☐ Repair		local systems, traceability, workflow fit, regulations, collection, economic viability
☐ Reuse		local systems, traceability, workflow fit regulations, collection, economic viability
☐ Refurbish		local systems, traceability, workflow fit, regulations, collection, economic viability
☐ Remanufacture		local systems, traceability, workflow fit, regulations, collection, economic viability
☐ Repurpose		traceability, function, adaptation, collection, economic viability
☐ Recycle		local systems, traceability, function adaptation, collection, economic viability
☐ Renew		traceability, workflow fit, regulations

The following page provides directions per system design consideration to initiate brainstorming. Aim to generate a full page of ideas for each circular strategy. Explore broadly first, then combine and refine the most promising ideas on the next page.

System Design Consideration

Main Responsibility

Operations & Supply Chain

Based on full team input

Use this page as a reference while completing the exercise on the previous page. Explore how the concepts developed in Phase B can facilitate multiple circular strategies. Refer to the **Circular Healthcare Flows visual** on page 52 to guide prioritisation.

Explanation of the System Design Considerations

Review the system design considerations and select those applicable to your device:

Local system	**Traceability**	**Workflow Fit**	**Function Adaptation**	**Regulations**	**Collection**	**Economic Viability**
Design for local or regional systems to minimise transport burden and support efficient handling and redistribution.	Enable device traceability and quality control through identifiers, cycle tracking, and audit logs for lifecycle oversight.	Ensure integration into clinical workflows through usability-focused design and validation with users for correct use and handling.	Enable modular or adaptable design features to support continued use in alternative applications where appropriate.	Engage early with regulatory requirements to ensure compatibility with applicable safety and compliance frameworks.	Ensure economic viability within healthcare operations. Detailed collection guidance on the next page.	Assess lifecycle cost-effectiveness while ensuring compatibility with healthcare workflows and system constraints.
Especially relevant if your hotspot is: **Transport**		Especially relevant if your hotspot is: **Use**			Especially relevant if your hotspot is: **Transport**	

Combine Ideas

From all the generated design ideas of Phase C page 28, explore how the most favourable ones can be combined together, and implemented into the ideas from Phase B, while also facilitating as many system design considerations as possible. Select at least 3 of the most promising ideas that you have now created. Write them down.

Design idea 1

Design idea 2

Design idea 3

Example of fully integrated system design of a smart pillbox on page 80.

Further iteration required?

Refine your ideas and revisit earlier phases as needed.

Phase A
Phase B
Phase C

Collection Path Ideation

Main Responsibility

Impact & Sustainability | Operations & Supply Chain | Clinical & End user

Input

Design & Engineer | Business & Strategy | Regulatory & Quality

For most post-use circular strategies, effective collection is required to enable further processing. This step defines how devices can be brought back into the system so they can be aligned with the circular strategies defined in Phase C page 29 and implemented in practice.

Understand your collection context

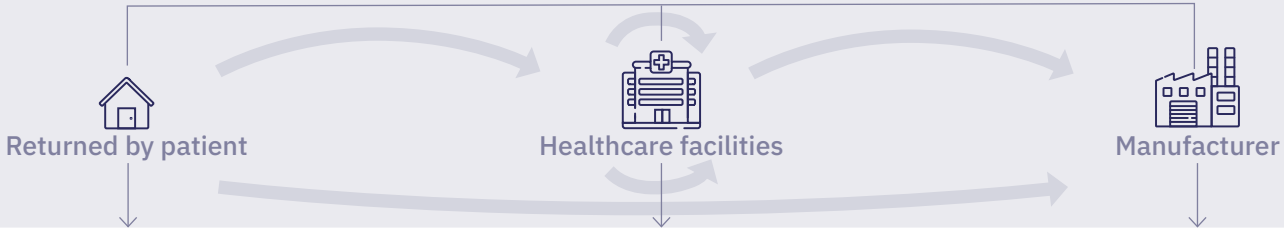
For each concept taken forward from Phase C page 29, engage with relevant stakeholders such as nurses, patients, sterile services staff, and logistics and waste operators to understand existing workflows or identify where new ones may need to be designed.

Use these insights to select the collection path(s) most suitable for the preferred ideas from Phase C page 29.

The chosen solutions should fit naturally within clinical practice and allow compliance with applicable local regulatory requirements for collection and reprocessing.

How is your device collected?

The following are examples of common collection approaches. Depending on the device and context, other paths or a combination may be more appropriate. If needed, follow multiple paths



Ensure Bring-Back

Design motivational strategies (in product, packaging, system) to stimulate and facilitate return.

Example: Prepaid return packaging or clearly communicated drop-off points for home blood pressure monitors, with instructions for the user to remove personal data before returning the device.

Detailed example on page 83

Allow in-Hospital Collection

Collect devices in the healthcare facility to directly clean and reuse them locally.

Example: Surgical instruments are sorted, cleaned, disinfected, and sterilized by central sterile services staff for safe reuse.

Detailed example on page 84

Ensure Take-Back

Have the manufacturer or a designated external stakeholder take back, clean, and prepare devices for reuse.

Example: Surgical drills are returned to the original manufacturer, cleaned, refurbished, and prepared for safe reuse.

Detailed example on page 85

Idea 1	Idea 2	Idea 3
System design considerations:	**System design considerations:**	**System design considerations:**
Preferred collection path(s) for this idea:	**Preferred collection path(s) for this idea:**	**Preferred collection path(s) for this idea:**

Wrap Up C (Concept Directions)

Main Responsibility

Operations & Supply Chain

Based on full team input

Use this page to summarise the three strongest concepts developed in Phase C. For each concept, document two things: the system design decisions made and the collection path that supports them. Together these form a consolidated record to carry forward into Phase D.

Concept 1 - Idea description, including the system design decisions

Most suitable collection path(s)	Collection & Destination point	Responsible stakeholder
☐ Bring-back ☐ Local collection ☐ Take-back		
Anticipated sustainability improvement	**Clinical benefits**	**Business benefits**

Concept 2 - Idea description, including the system design decisions

Most suitable collection path(s)	Collection & Destination point	Responsible stakeholder
☐ Bring-back ☐ Local collection ☐ Take-back		
Anticipated sustainability improvement	**Clinical benefits**	**Business benefits**

Concept 1 - Idea description, including the system design decisions

Most suitable collection path(s)	Collection & Destination point	Responsible stakeholder
☐ Bring-back ☐ Local collection ☐ Take-back		
Anticipated sustainability improvement	**Clinical benefits**	**Business benefits**

EMBODY

Making Devices Last

This phase shifts the focus from system-level decisions to the product itself, translating general concepts into concrete, buildable design choices. Using the hotspots from Phase A and the circular strategies from Phase C as a guide, this phase implements the chosen strategies directly into the device design, applies relevant requirements, and addresses common development barriers specific to medical device development.

› Go back to Circular Strategies in Phase C page 25

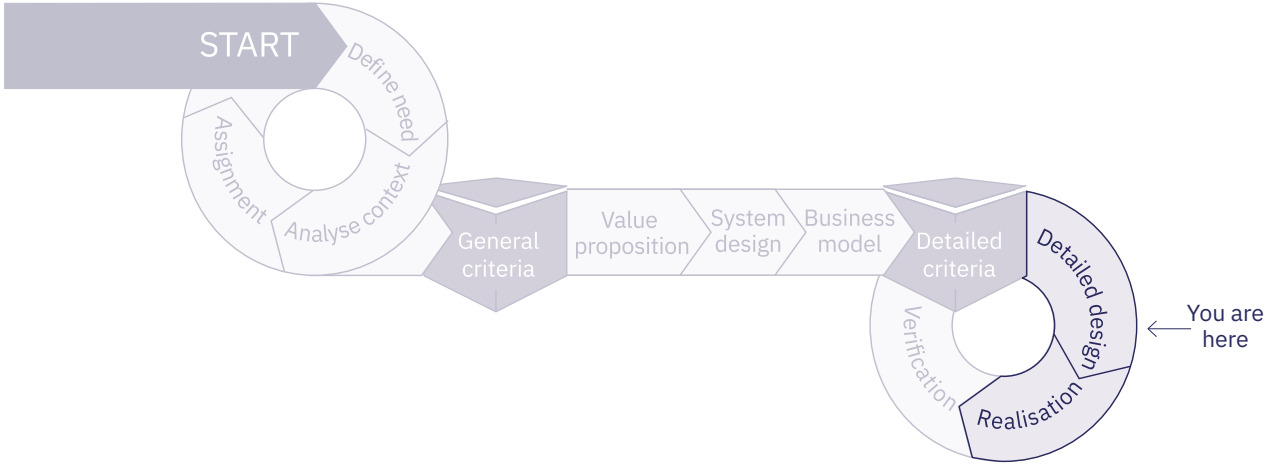
Main Responsible Roles

- Design & Engineering
- Impact & Sustainability
- Operations & SupplyChain
- Business & Strategy
- Regulatory & Quality
- Clinical & End user

Which circular strategies are involved in this phase?

All strategies aimed at making device (components) last, as well as strategies aimed at recovering raw materials:

5 Maintain · 6 Repair · 7 Reuse · 8 Refurbish · 9 Remanufacture · 10 Repurpose · 11 Recycle · 12 Renew



› Glossary page 92

Watch the Video

Embody Circular Strategies

Develop multiple embodiment ideas for each circular strategy Phase C page 26-27, applying the relevant embodiment criteria which will be elaborated on further on the next page. Overarching the circular strategies apply material selection, component design and manufacturing approach considerations as discussed in Phase D page 36.

Main Responsibility

- Design & Engineer
- Impact & Sustainability

Input

- Regulatory & Quality
- Operations & Supply Chain
- Clinical & End user

	Ideas	Embodiment design considerations
☐ Maintain		disassembly, longevity, value perception, clinical safety, quality assessment, traceability
☐ Repair		disassembly, longevity, value perception, clinical safety, quality assessment, traceability
☐ Reuse		disassembly, longevity, value perception, clinical safety, patient privacy, quality assessment, traceability, cleanability
☐ Refurbish		disassembly, longevity, value perception, clinical safety, patient privacy, quality assessment, traceability, cleanability
☐ Remanufacture		disassembly, longevity, value perception, clinical safety, patient privacy, quality assessment, traceability, cleanability, depollution
☐ Repurpose		longevity, clinical safety, patient privacy, quality assessment, traceability, cleanability
☐ Recycle		clinical safety, quality assessment, traceability, material separation, depollution
☐ Renew		clinical safety, degradability, material separation, depollution

Visit the next page for further details on the various embodiment design considerations.

Embodiment Details to Consider

Select a Phase C idea and a relevant matrix row (per the previous page) to map concepts to physical details. Repeat as needed.

Main Responsibility

- Design & Engineer
- Impact & Sustainability

Input

- Regulatory & Quality
- Operations & Supply Chain
- Clinical & End user

CONSIDERATION from the previous page	Embodiment ideas to brainstorm on				Additional Links
Disassembly	☐ Minimize # of components used	☐ Create modular sub assemblies	☐ Avoid use of adhesives	☐ Improve accessibility (standardization)	> 84 Assembly methods suitable for disassembly
Longevity	☐ Use durable materials	☐ Clear/accessible user instructions	☐ Enable product updates	☐ Ensure well-fitting parts assembly	
Value perception	☐ Increase emotional attachment	☐ Ensure perceived high financial value	☐ Ensure perceived high function value	☐ Ensure perceived high efficiency value	
Clinical safety	☐ Minimize infection risk	☐ Maintain device quality and function	☐ Avoid/cover toxins and sharps if possible	☐ Avoid unintended biological interaction	
Patient privacy	☐ Ensure to delete patient data from device	☐ Secure data storage properly	☐ Ensure perceived data privacy	☐ Avoid unauthorized access to device	
Degradability	☐ Use biodegradable materials (if safe)	☐ Avoid chemical residue (risks)	☐ Avoid unintended biological interaction	☐ If safe, speed up composting proces approved biobased material	> 85 Medically Approved Biobased Material
Quality Assessment	☐ Ensure well-defined, measurable criteria	☐ Ensure efficient quality test method	☐ Determine negative test consequences	☐ Assure assessment generalizability	
Traceability	☐ Ensure easy/safe to access product info	☐ Track number of cycles per product	☐ Count the cycles per part or material	☐ Provide extensive material/defects info	
Cleanability	☐ Choose cleaning compatible material	☐ Minimize # of components used	☐ Avoid shapes that cause dirt build-up	☐ Waterproof the device if needed	> 91 Decontamination strategies/guidance
Material separation	☐ Minimize number of materials used	☐ Avoid use of mixed materials	☐ Choose higher value materials if possible	☐ Avoid adhesive assembly methods	> 85 Materials compatible in recycling
Depollution	☐ Minimize hazardous substances use	☐ Ensure batteries are easy to remove	☐ Indicate use of toxins clearly (if included)	☐ Make toxins easily and safely removable	> 85 Medically Approved Recyclable Materials

Disassemble your device Disassemble your device or a similar one and document every component and material. Map each material to its environmental impact.

Optimize Your Circular Design

Main Responsibility

Design & Engineer

Impact & Sustainability

Input

Regulatory & Quality

Operations & Supply Chain

Clinical & End user

In embodiment design, three categories of considerations are relevant across all circular strategies for the device. These considerations provide an overarching lens for evaluating strategies during the brainstorming process in Phase D page 34-35.

Material Selection

Consider the following criteria when selecting materials.

- ☐ Assess material choices from a life cycle perspective. Select bio-based or renewable materials only where environmental benefits have been demonstrated.
- ☐ Where trade-offs exist, prioritise durability over recyclability for devices intended for multiple use cycles.
- ☐ Minimise material use without compromising safety, quality, or performance.

Component Design

Consider the following criteria when defining components.

- ☐ Prioritize durability, reuse, or replacement strategies for components associated with significant environmental impacts.
- ☐ Design wear-prone or contamination-sensitive components to be replaceable, repairable, or serviceable where feasible.
- ☐ Where relevant, align component lifetimes with the intended service life and use cycles of the overall device.

Manufacturing Approach

Consider the following criteria when selecting manufacturing processes.

- ☐ Where relevant, select manufacturing methods that minimize life cycle impacts while maintaining material quality and enabling effective recovery and reprocessing.

Address Common Implementation Barriers

Circular strategies can introduce technical, regulatory, financial, and organizational changes. Consider how you might overcome common barriers below.

Main Responsibility

Design & Engineer

Impact & Sustainability

Input

Regulatory & Quality

Operations & Supply Chain

Clinical & End user

Overcome the most Common Implementation Barriers

Not all barriers will apply to every device. Focus on the ones which are most relevant to your product, context, and circular strategy.

(Perceived) safety risks	Potential Mitigation Strategies		
Concerns regarding contamination, infection control, or patient safety can limit the adoption of circular solutions.	Question: are these risks real?	Mitigate through proper decontamination .	> Check the decontamination page 91 again

Regulatory compliance	Potential Mitigation Strategies		
Circular medical devices do not always fit all regulations.	Understand the regulatory landscape.	Revisit the regulation to check if interpretations are correct.	Engage regulators early and start piloting. Click for more inspiration

Technological limitations	Potential Mitigation Strategies	
Some medical devices are either outdated, or too innovative to realize.	Evaluate limitations: can you engineer differently?	If this is a real problem, revisit Phases A and B to see if the vision for your device can be improved.

Financial Constraints	Potential Mitigation Strategies	
Circularity may require investments or complicate business models.	Create a circular business model and develop a financially viable implementation roadmap.	> Example on page 88 Financial constraint —or fear? Discover how circular design drives value in medical imaging.

Stakeholder acceptance	Potential Mitigation Strategies	
Circular medical devices may not always be accepted by user or patient.	Build trust by prioritizing and communicating safety and performance benefit.	Prioritize the perceived value-related criteria and apply co-creation.

The following page provides examples for adapting to barriers

Adapting to Barriers

Main Responsibility

Design & Engineer

Impact & Sustainability

Input

Regulatory & Quality

Operations & Supply Chain

Clinical & End user

Examples of adaptations for barriers that cannot be prevented or overcome

Hybrid design

Laparoscopic device has a reusable electronics unit with recyclable plastic handle.

Refill design

Autoinjector cartridges are replaced regularly, keeping the main device in continuous use.

Sleeve design

Ultrasound probe uses a disposable sleeve, avoiding the need for disposal of electronics.

Detailed examples on page 89

TASK

Brainstorm mitigation strategies Develop a mitigation strategy for all columns. For example, find a decontamination strategy for each concept that aligns with the intended use, criticality level, and circular strategies selected. In this case, consider that overcleaning generates unnecessary environmental impact.

Wrap Up D

Main Responsibility

Design & Engineering

Business & Strategy

Input

Impact & Sustainability

Use these pages to document at least three of your strongest device concepts from the previous pages. For each, describe the concept and record the key design decisions and insights from this phase, providing a clear and evidence-based foundation for the evaluation ahead.

Concept 1 - description

Embodiment

Barriers this concept might encounter	Strategies to overcome these barriers

Concept 2 - description

Embodiment

Barriers this concept might encounter	Strategies to overcome these barriers

Concept 3 - description

Embodiment

Barriers this concept might encounter	Strategies to overcome these barriers

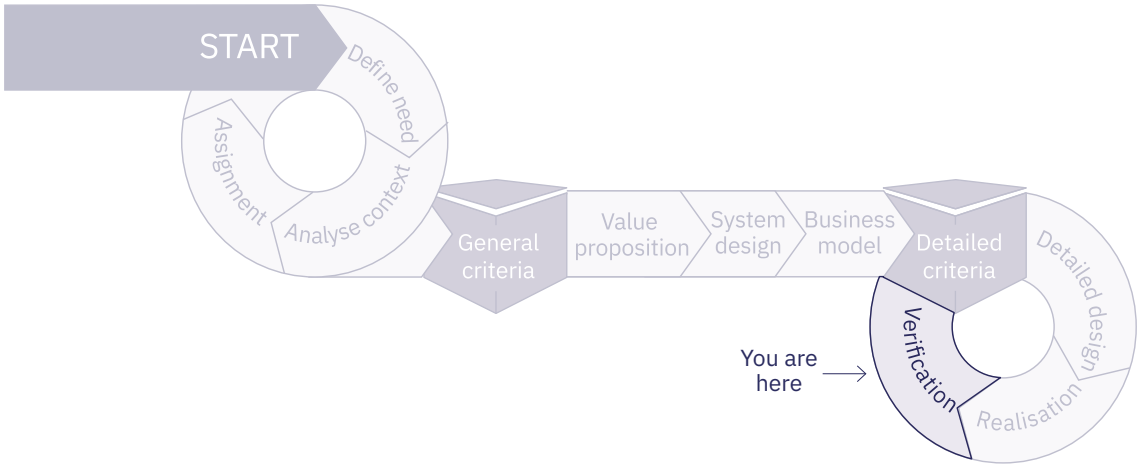
EVALUATE

Determine True Impact

In this phase, you quantitatively estimate the environmental and clinical / business benefits of all your best ideas. Assessing your new ideas objectively, either against each other or against the current standard of care, lets you make evidence-based decisions about which idea(s) to implement. This helps you avoid greenwashing or wasted money and time, and ideas not feasible now can be set aside for the future.

Main Responsible Roles

- Design & Engineering
- Impact & Sustainability
- Operations & SupplyChain
- Business & Strategy
- Regulatory & Quality
- Clinical & End user



Glossary page 92

Watch the Video

Evaluate the Sustainability of Your Concepts

Use the tools below to assess each design concept for demonstrable gains in sustainability and to identify any factors that could offset those gains.

Main Responsibility

Impact & Sustainability

Input for decision-making

Business & Strategy

Design & Engineer

Clinical & End user

Methods to Analyse the Environmental Sustainability

Using the same life cycle assessment method (or other metric) you used in Phase A, evaluate the environmental impact of each device concept and benchmark against each other and/or the current standard of care to identify which concept delivers the greatest improvement.

Social Evaluation

In addition to environmental evaluation, please also consider social sustainability of your device concept to ensure it prioritises human welfare, equity, basic human rights, and inclusivity.

Possible rebound effects

Circular solutions can introduce unintended consequences that offset their sustainability gains. When evaluating device concepts, consider whether the solution could introduce any adverse effects and anticipate where relevant.

Example

Increased patient complications

e.g., reusable catheter may be harder to clean, increasing infection risk and resource use for additional treatments.

Example

Increased hospital readmissions

e.g., refurbished orthopedic implants need additional monitoring, increasing travel and hospital resource use.

Example

More safety equipment needed

e.g., complex reusable endoscopes may require extra PPE, cleaning agents, and energy during reprocessing.

Review

Review potential unintended consequences for each of your device concepts and know how to mitigate them. Consider these when estimating impacts through the metrics used in Phase A.

Review the outputs from Phases B, C, and D to identify where unintended consequences are most likely to arise.

Wrap Up E

Compare the environmental impact of at least three strong concepts against the baseline from Phase A to identify which delivers the greatest improvement. Document and share this gain with your organisation to be able to justify the development.

Main Responsibility

Business & Strategy

Impact & Sustainability

Input

Design & Engineer

Clinical & End user

Decision Matrix

The decision matrix supports structured assessment and prioritisation of created concepts for subsequent development phases. Position the different concepts in the assigned columns, with the assessment criteria formulated in the rows. For the sustainability score, use the percentage of improvement calculation from the previous page. To determine the business/clinical value, define relevant assessment criteria such as incubation time, investment cost, return on investment, manufacturability, bill of materials, performance, usability, and hospital workflow integration. Score each concept from **1** ***(much worse than baseline) to*** **3** ***(same as baseline) to*** **5** ***(much better than baseline)*** and assign a criteria weight from **1** ***(low) to*** **5** ***(high) importance***. Multiplying scores by weights and summing results provides a transparent ranking to support selection decisions. Consider integration of social impacts in the sustainability score. Ensure you can justify the rationale and criteria used to determine each concept's score.

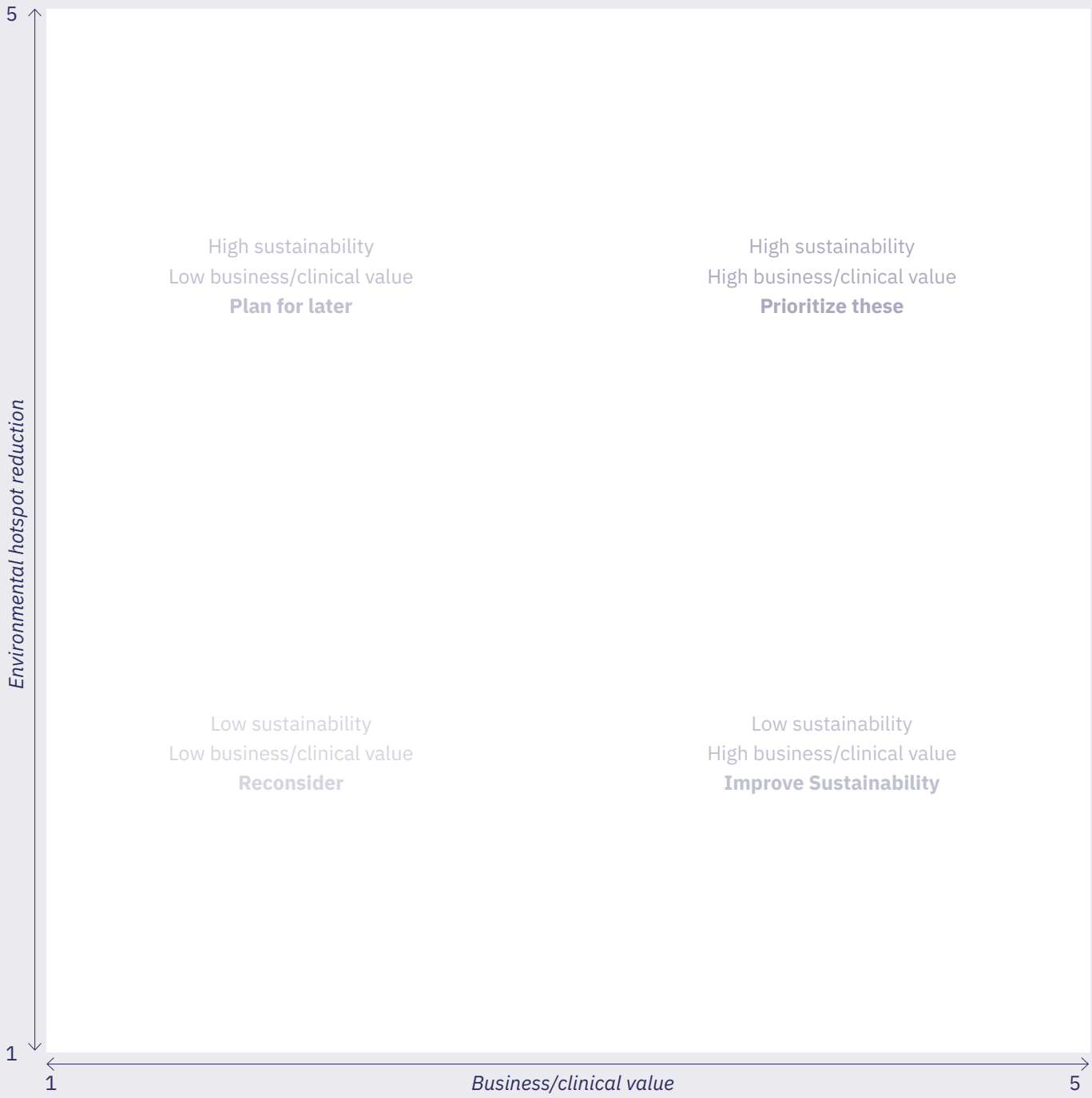
Sustainability Score	Concept 1	Concept 2	Concept 3
Expected reduction of the identified environmental hotspots	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Business/Clinical Value Score	Criteria Weight	Concept 1	Concept 2	Concept 3
Assessment Criteria I	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5,	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Assessment Criteria II	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5,	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Assessment Criteria III	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5,	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
$= \frac{\text{sum of (criteria score} \times \text{weight)}}{\text{sum of weights}}$			

The concept with the highest total score, assuming the weighting reflects stakeholder priorities, is likely the strongest candidate to take forward. If a concept scores low, return to Phase B to explore further opportunities to reduce impact before proceeding.

Implementation Matrix

Fill in the implementation matrix on the left to determine your focus. Use the environmental improvement score from Phase E page 43 to determine the position of your concepts on the vertical axis. Use the business value score of the decision matrix to determine its position on the horizontal axis.



Wrap Up E

With the strongest concept(s) selected, use the implementation matrix below to create a concrete action plan. Decide which concepts are most relevant to implement now and which to schedule for a later stage.

Main Responsibility

- Business & Strategy
- Impact & Sustainability

Input

- Design & Engineer
- Clinical & End user

Implement now

Idea/Action	
Expected Benefits (e.g.% CO_2 reduction, kg waste avoided)	

More ideas can be listed, if desired.

Plan for later

Idea/Action	
Expected Benefits (e.g.% CO_2 reduction, kg waste avoided)	
When	

More ideas can be listed, if desired.

Implementation
Take the strongest concept forward and begin executing.

Designed to Circulate

With this guide, you have produced circular concepts for the medical device, providing a foundation for reducing environmental impact while maintaining clinical, technical, and economic performance.

What you have achieved

This process has covered the key phases of developing a circular medical device, from identifying environmental hotspots and exploring circular strategies to translating these into concrete design decisions that reduce environmental impact and extend the life of products, components, and materials.

What comes next

With a circular device concept chosen, the next step is to further develop, test, and refine the device or service and its ideas. Continued stakeholder involvement throughout the process will ensure feedback guides future iterations. Following implementation, monitor how the device performs in practice and identify opportunities to further strengthen circular performance where appropriate.

Go Beyond

Designing a circular device or service is one step towards more sustainable healthcare. Additional opportunities for impact can be found beyond this, for example in healthcare systems, supply chains, procurement practices, business models, and policy.

One approach is to consider how healthcare could operate in the coming decades and what changes are required to achieve that vision. Thinking beyond individual products can help identify opportunities to accelerate circularity at a broader system level.

Want to know more

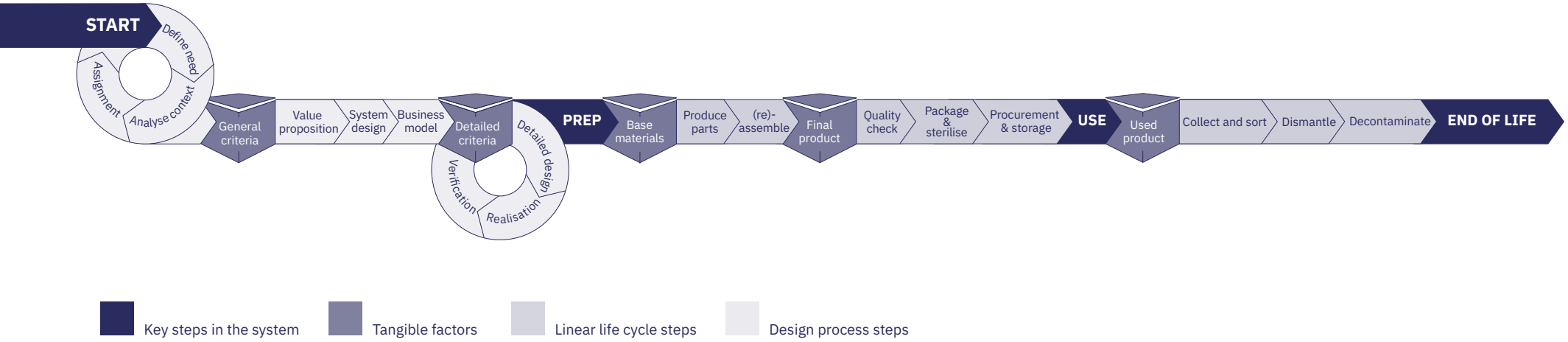
- Link to dissertation T. Hoveling, repository.tudelft.nl
- EU website, on future regulations, eur-lex.europa.eu
- Department of Sustainable Design Engineering | TU Delft, tudelft.nl/en/ide/about-ide/departments/sustainable-design-engineering
- DesHealth book, sustainablehospital.org/guide
- Sustainable Design from Vision to Action: http://sdva.green/

Digital Health in the Circular Economy

Circular Healthcare Flows

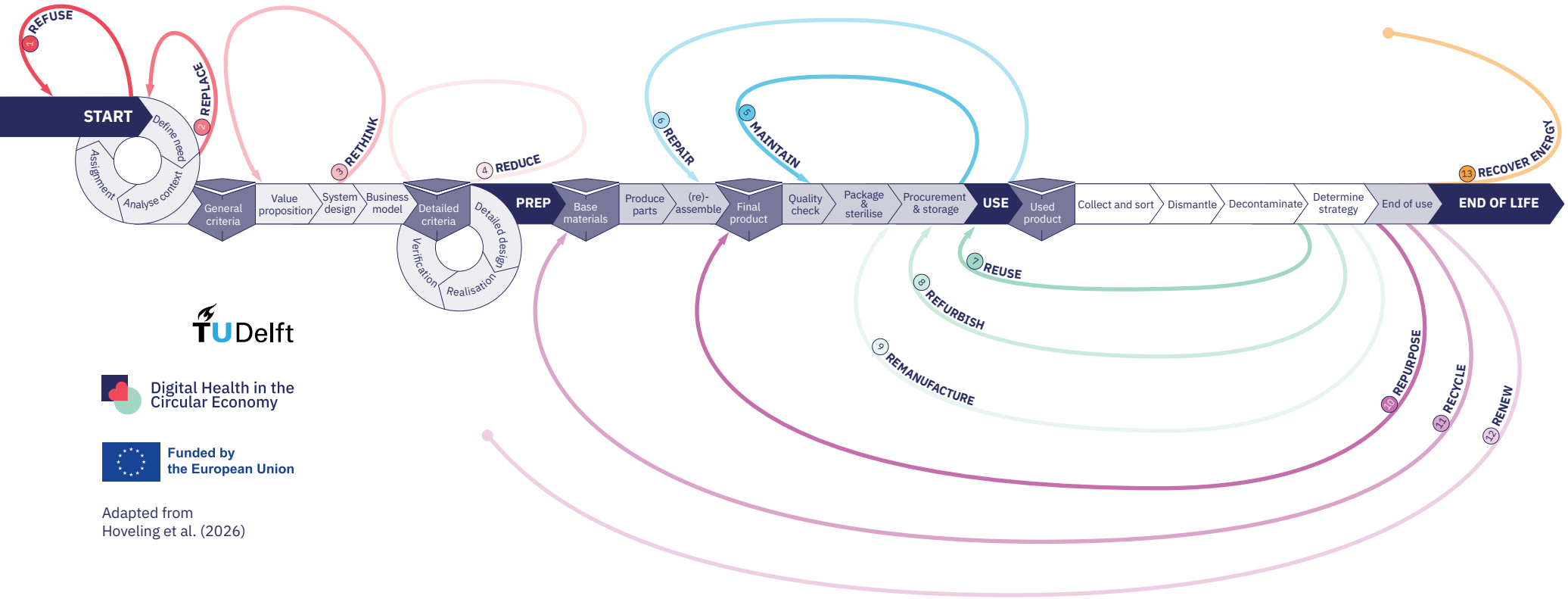
Medical Device's Linear Life Cycle

The diagram below represents the conventional life cycle of medical devices within today's healthcare system. In this predominantly linear model, devices progress through development, manufacturing, distribution, use, and disposal, with limited recovery of devices, components, or materials at the end of use. Most are simply discarded and incinerated at the end of life. Have a look at the circular life cycle on the next page to learn how to develop more sustainable devices.



Circular Healthcare Flows

The diagram below represents a circular life cycle of medical devices and the circular strategies introduced to make it happen. These strategies help to extend the useful life of products, components and materials and should already be incorporated during device development.



TU Delft

Digital Health in the Circular Economy

Funded by the European Union

Adapted from
Hoveling et al. (2026)

Circular Strategy Definitions

This page defines the circular strategies and the life cycle stages in which they are typically applied. Strategies earlier in the hierarchy are generally more impactful than those later in the life cycle.

I Research, Design, and Development

1 Refuse

The intentional act of rejecting the production, consumption, or use of a medical product, material, or procedure, particularly those that are unnecessary, unsustainable, or harmful.

2 Replace

Substituting a medical product or procedure with an alternative that serves the same purpose but significantly reduces environmental impact.

3 Rethink

Systemically enhancing the procedures surrounding product use to drive environmentally sustainable practices, such as through rethinking patient transport and telemedicine, sharing products or introducing multifunctionality.

4 Reduse

Increasing efficiency in healthcare delivery and medical manufacturing by minimising energy and resource use, avoiding unnecessary production or consumption, limiting hazardous substances, and minimising (unnecessary) procedures.

II Performance Preservation

5 Maintain

Preserving the quality, function, and safety of medical products and clinical environments to ensure reliable performance, extend their lifespan, and reduce the risk of malfunctions that could lead to potential treatment failures.

6 Repair

Restoring a faulty or broken product or component to a usable state to fulfil its intended use, which typically involves corrective maintenance, ensuring that safety and performance specifications are met for an extended period of time.

III Take-Back and Decontamination

No circular strategies but a step-by-step guide on take-back and decontamination.

IV Reprocessing for Intended Use

7 Reuse

Repeated use of a medical device on multiple patients for the same intended purpose, after decontamination when needed, and without significant modification.

8 Refurbish

Restoring a product to good working condition through decontamination, repairs, upgrades, cosmetic changes, performance checks, reinstallation, warranty assurance, and parts replacement.

9 Remanufacture

Restoring products and components, often utilizing parts from discarded products, to achieve as-new condition through disassembly,

decontamination, quality control, certification, repackaging, and redistribution.

V Research, Design, and Development

10 Repurpose

Using discarded products or parts for different purposes than originally intended, such as in varied contexts (e.g. veterinary care procedures), purposes (e.g. different human procedures) and locations (e.g. developing countries).

11 Recycle

Transforming waste materials from used products or resources into new raw materials, either of the same or lower quality, through e.g. decontamination, shredding, and moulding.

12 Renew

Transforming waste materials, energy sources, and other substances into basic elements like carbon dioxide, water, biomass, or human tissue (for regenerative medicine) through natural processes.

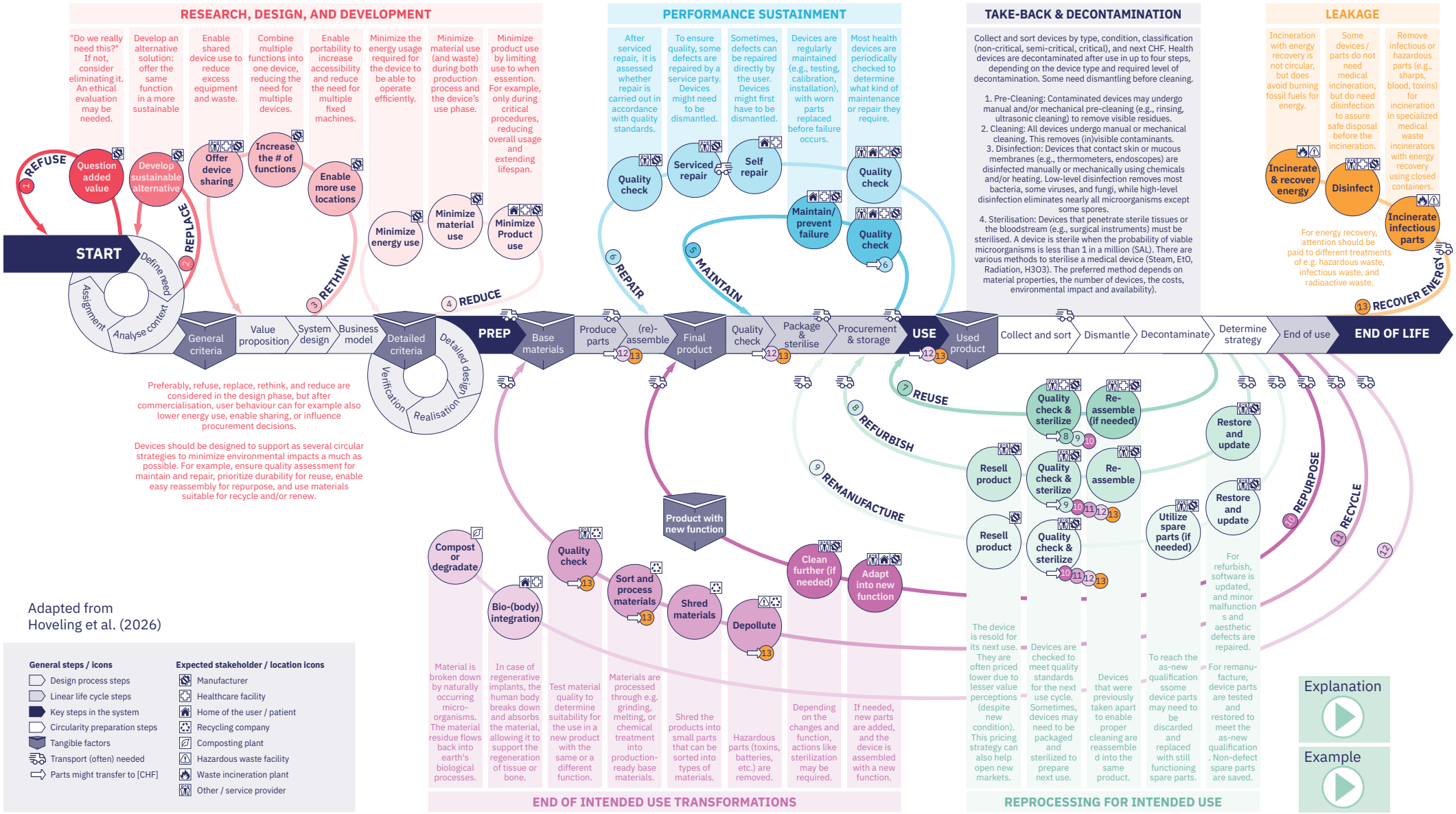
VI Leakage

13 Recover Energy

Incineration (or medical incineration) of waste materials with energy recovery.

This space previously
contained the A2 poster
in the printed version.

Circular Healthcare Flows visual



Adapted from
Hoveling et al. (2026)

EXAMPLES

Refuse 1 Example 1

Page 18

UV-Light Toothbrush Sanitizers

UV-light toothbrush sanitizers are designed to eliminate bacteria on toothbrush bristles using UV-C light technology. These devices are marketed as hygiene solutions that provide additional cleaning after brushing, although their added value compared with regular toothbrush care remains limited in routine use.

Why we recommend to Refuse

There is currently no strong scientific evidence that UV-light toothbrush sanitizers provide meaningful improvements in oral health beyond the benefits achieved through proper brushing techniques, regular toothbrush replacement, and standard hygiene practices. While these devices are marketed as additional sanitation solutions, their clinical value remains uncertain in routine dental care.

Without demonstrated improvements in patient outcomes, the environmental impacts associated with producing, using, and disposing of these devices are difficult to justify. UV toothbrush sanitizers require additional materials, electronic components, energy consumption, packaging, and manufacturing resources compared with conventional toothbrush care practices. These impacts occur without clear evidence of a corresponding health benefit. Removing products that provide limited clinical value can help avoid unnecessary resource use and prevent the generation of avoidable electronic waste. Prioritising evidence-based oral hygiene practices allows healthcare systems and consumers to focus on interventions with proven benefits while supporting more sustainable choices.

For this reason, UV-light toothbrush sanitizers represent a strong candidate for market removal. Eliminating low-value devices can contribute to more sustainable healthcare by ensuring that resources are directed toward solutions that deliver measurable improvements in health outcomes.

Benefits of Refusing

Less electronic waste

Lower energy consumption

Less plastic production

Fewer transport requirements

Key Take-Away

A medical device's added value should justify its environmental impact, ensuring resources support meaningful improvements in patient care.

Refuse 1 Example 2

Page 18

Bloodletting Cupping Devices

Some cupping devices enable bloodletting, involving the controlled withdrawal of blood from the body. These devices are promoted for potential therapeutic benefits, including pain relief and management of chronic conditions, although clinical evidence supporting their effectiveness and added value remains limited compared with established treatments.

Why we recommend to Refuse

Evidence from systematic reviews indicates that bloodletting cupping provides little or no reliable therapeutic benefit for pain management or chronic conditions. While these devices are promoted as alternative treatment options, available evidence does not demonstrate consistent improvements in patient outcomes compared with established therapies. Additionally, their use carries potential risks, including skin irritation, bleeding complications, and infection.

Because bloodletting cupping devices come into direct contact with blood, they often require handling and disposal as potentially hazardous medical waste after use. This creates additional environmental and operational burdens for healthcare facilities, including specialised waste processing and increased disposal requirements.

Many bloodletting cupping systems also contain plastic components, such as valves, pumps, and collection chambers, which can be difficult to recycle due to contamination risks. Some products are designed for single use, increasing material consumption and waste generation. When devices provide limited clinical value while creating additional environmental impacts, their continued use becomes difficult to justify. Removing these products from circulation supports more sustainable healthcare by prioritising interventions with proven benefits, reducing unnecessary waste streams, and directing resources toward effective patient care solutions.

Benefits of Refusing

Less hazardous medical waste

Less disposable components

Lower regulatory constraints

Reduced adverse effect risks

Key Take-Away

Medical devices should only be used when proven therapeutic value outweighs environmental impacts, risks, and waste generation.

Replace[2] Example 1

Page 19

Premature Infant Ventilators

Mechanical ventilation is often required to support premature infants with respiratory distress. While advances in ventilator technology have led to the development of new devices, many improvements in neonatal respiratory care can be achieved by optimising ventilation strategies and settings on existing equipment, rather than introducing new devices.

Why we recommend to Replace

Evidence shows that lung-protective ventilation strategies—such as appropriate tidal volumes, positive end-expiratory pressure (PEEP), targeted oxygen levels, and timely weaning—can reduce ventilator-induced lung injury and improve outcomes for premature infants. These improvements are primarily achieved through effective ventilator management and clinical practice, rather than through the introduction of newer equipment.

Optimising the use of existing ventilators enables healthcare teams to provide high-quality, evidence-based respiratory care while extending the lifespan of available devices. Avoiding unnecessary replacement reduces the environmental impacts associated with manufacturing, transportation, packaging, and disposal of new equipment, including greenhouse gas emissions and resource consumption.

Where existing ventilators continue to meet safety and performance requirements, investments in staff training, evidence-based protocols, and preventive maintenance can deliver greater clinical and environmental value than replacing functional devices. New ventilators remain important when current equipment cannot support patient needs, lacks essential features, or no longer meets safety standards. By prioritising optimal use of existing technology, healthcare systems can maintain quality neonatal care while reducing avoidable resource use and supporting more sustainable medical practices.

Benefits of Replacing

Better use of existing equipment

Longer ventilator lifespan

Less medical equipment waste

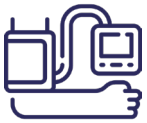
Lower manufacturing and carbon footprint

Key Take-Away

Using existing ventilators instead of developing new devices lowers environmental impact while maintaining effective respiratory support for premature infants.

Replace[2] Example 2

Page 19



Electronic Blood Pressure Monitors

Blood pressure can be measured manually or with electronic monitors using oscillometric sensors for automatic measurement and digital display. Because they are convenient, easy to use, and provide rapid readings, electronic blood pressure monitors are widely used in hospitals, clinics, and other healthcare settings.

Why we recommend to Replace

Digital blood pressure monitors provide moderate diagnostic accuracy compared with manual measurement, with a pooled sensitivity of approximately 79% for detecting hypertension. This indicates that while digital devices are effective for routine screening and monitoring, manual blood pressure measurement remains a reliable alternative in stable care settings when performed correctly by trained healthcare professionals.

In addition to providing comparable clinical outcomes in many routine situations, manual blood pressure devices have a substantially lower environmental footprint. They require no electricity or batteries, contain no electronic components, and generally have longer service lives with fewer replacement needs. As a result, they generate less electronic waste and have lower resource and energy demands across their lifecycle than digital monitors.

When there is no meaningful difference in patient outcomes, selecting the option with the lower environmental impact supports more sustainable healthcare delivery. Therefore, for routine blood pressure measurement in stable patients, manual devices represent a practical and environmentally preferable choice while maintaining acceptable clinical performance. Digital monitors remain valuable where automation, rapid repeated measurements, or specific patient needs make them the more appropriate option.

Benefits of Refusing

No battery or energy required

No electronic components or e-waste (no CRM involved)

Longer device lifespan

Lower manufacturing footprint

Key Take-Away

Where clinical reliability is comparable, the simpler, lower-impact option should be preferred to reduce environmental impact without compromising patient care.

Rethink[3] Example 1 - Multifunctionality

Page 20

Integrated Oxygen Delivery and Oximetry

Pulse oximeters measure blood oxygen saturation (SpO_2) and pulse rate, while oxygen masks and nasal cannulas provide supplemental oxygen. These functions are traditionally delivered by separate devices, each requiring its own materials, packaging, maintenance, and replacement throughout its life cycle.

Why we recommend to Rethink

Combining oxygen delivery and pulse oximetry into a single multifunctional device offers an opportunity to optimise resource use while maintaining effective patient care. An oxygen mask or nasal cannula with integrated SpO_2 sensors could provide oxygen therapy while continuously monitoring oxygen saturation, eliminating the need for separate delivery and monitoring devices.

This integrated approach reduces the number of devices required during treatment, decreasing material consumption, packaging, manufacturing, transportation, cleaning, and end-of-life waste. It may also simplify procurement and inventory management by reducing the number of products healthcare organisations need to purchase, store, maintain, and replace. For healthcare professionals, multifunctional devices can improve workflow by reducing device handling, simplifying setup, and minimising clutter around the patient.

Successful implementation requires integrated devices to maintain reliable clinical performance, usability, and patient safety. When multifunctional designs provide equivalent functionality to separate devices, replacing multiple products with a single solution supports more sustainable healthcare delivery. This approach promotes efficient medical device design by reducing unnecessary resource use while maintaining high-quality patient care. By combining essential functions into one device, healthcare systems can reduce environmental impact without compromising clinical effectiveness, safety, or patient outcomes.

Benefits of Replacing

Fewer devices required during treatment

Reduced material use and packaging

Lower life-cycle environmental impact

Simplified clinical workflow

Key Take-Away

When related clinical functions can be safely integrated, multifunctional devices reduce resource consumption while simplifying healthcare delivery.

Combining ECG and SpO_2 Monitoring

Electrocardiogram (ECG) and pulse oximetry (SpO_2) monitoring are commonly used together to assess patient vital signs. Combining these functions into a single device or integrated system can reduce the number of separate components required and appears to offer a more resource-efficient solution.

Good intention

Integrate ECG and SpO_2 monitoring to reduce disposable components, simplify equipment use, and lower material consumption. Combining monitoring functions aims to improve workflow efficiency by reducing the number of separate devices required at the patient bedside. However, this approach should consider the full lifecycle impact, including cleaning requirements, maintenance needs, energy use, and device complexity. A reduction in disposables does not always result in a lower environmental footprint if additional operational burdens are introduced. Sustainable solutions should balance resource efficiency with practical clinical use and long-term environmental performance.

Bad consequence

Integrated systems may increase cleaning requirements, maintenance needs, and device complexity. While combining ECG and SpO_2 monitoring can reduce disposable components, these benefits may be offset by additional resource demands throughout the device lifecycle. More frequent cleaning, specialised maintenance procedures, and increased use of cleaning materials can contribute to higher environmental impacts. Device complexity may also require more technical support, energy use, and replacement components over time. Therefore, evaluating sustainability requires considering the complete system impact, rather than focusing only on reductions in disposable materials.

Why the habit backfires

- **Combining functions does not always reduce total environmental impact when additional cleaning, maintenance, and operational requirements are introduced.**
- **More complex devices may require specialised handling, increasing resource use throughout their lifecycle.**
- **Sustainability decisions should consider the full system impact, including cleaning, energy use, and maintenance—not only disposable reduction.**

Key Take-Away

Reducing disposables does not always lower environmental impact. Sustainable design must consider the complete lifecycle of the device and its supporting processes.

Rethink 3 Example 2

Page 20

Standardised Ultrasound Platforms

Standardising ultrasound platforms by separating probes from dedicated displays allows use of existing hospital hardware. This approach can reduce unnecessary equipment duplication, extend device lifespan, and avoid replacing complete systems when only specific components require updating or replacement.

Why we recommend to Rethink

Medical devices are often developed as closed systems with proprietary hardware, software, and interfaces. While this approach can simplify product integration, it may also create unnecessary duplication of components across healthcare facilities. Displays, processors, batteries, and other electronic elements are frequently manufactured, purchased, and maintained separately, even when similar functions could be supported through shared or compatible infrastructure.

By standardising interfaces and enabling compatibility with existing hardware platforms, manufacturers can reduce the need for dedicated components and support more efficient use of healthcare resources. Hospitals may be able to upgrade or replace individual components rather than entire systems, extending the useful life of existing equipment and limiting electronic waste generation.

Standardisation across product generations, ensuring that older and newer versions remain compatible, can improve deployment flexibility and reduce unnecessary replacement cycles. Although technically feasible, interoperability is often not prioritised because proprietary ecosystems encourage continued purchasing of manufacturer-specific equipment. When healthcare organisations require interoperability and upgradeability, standardisation becomes a driver for more sustainable medical device design, improving long-term value and supporting responsible resource use.

Benefits of Rethinking

Less electronic waste through component-level upgrades

Lower material use through shared infrastructure

Extended lifespan of existing equipment

Greater interoperability and upgrade flexibility

Key Take-Away

Standardised medical device platforms enable shared infrastructure, reduce resource use, extend equipment lifespan, and support sustainable healthcare without compromising clinical performance.

Standardising Patient Monitors

Patient monitors support vital sign tracking and clinical decision-making. Standardising these systems across healthcare facilities can improve consistency, simplify staff training, and streamline procurement, maintenance, and device management. However, standardisation should maintain flexibility and compatibility to avoid unnecessary replacement of functional equipment when technologies evolve.

Good intention

Standardising patient monitors improves interoperability, simplifies workflows, and increases efficiency across healthcare departments. Using a uniform monitoring system enables healthcare professionals to work with familiar equipment, standardised interfaces, and consistent processes, reducing complexity and training needs. It also supports more efficient procurement, maintenance, and equipment management. By creating a common platform, healthcare organisations can improve coordination between departments, streamline clinical operations, and support reliable patient care alongside more effective resource management.

Bad consequence

Over-standardisation can reduce flexibility and create dependence on a single manufacturer. Software updates, hardware upgrades, or compatibility requirements may force replacement of clinically functional equipment, increasing electronic waste and resource use. Closed systems can limit interoperability with alternative technologies, leading to unnecessary replacement cycles. Without sufficient interoperability, standardisation may increase costs, shorten equipment lifespans, and undermine its intended environmental and operational benefits.

Why the habit backfires

- **Standardised systems may accelerate replacement cycles when older devices become incompatible with newer versions.**
- **Closed ecosystems can limit flexibility and increase dependence on a single manufacturer.**
- **A focus on uniformity may overlook opportunities to extend the lifespan of existing equipment through adaptable and interoperable solutions.**

Key Take-Away

Standardisation should support compatibility and longevity, not create unnecessary replacement cycles. Flexible systems enable efficiency while preserving existing resources and reducing waste.

Rethink ③ Example 3

Page 20

Clinical Ventilator

Clinical ventilators provide life-critical respiratory support for patients unable to breathe independently. Traditionally, each ventilator supports one patient at a time, requiring hospitals to maintain large fleets. Many devices remain unused during normal periods, creating ongoing costs, storage needs, maintenance requirements, and environmental impacts.

Why we recommend to Rethink

Current ventilator design is based on a one-device-per-patient model. While this approach simplifies clinical operation and ensures dedicated respiratory support, it requires healthcare systems to maintain large equipment capacity to accommodate fluctuations in patient demand. During periods of lower demand, many ventilators remain unused while still requiring storage, maintenance, and eventual replacement.

Research from MIT and Brigham and Women's Hospital has demonstrated that purpose-designed ventilator splitting systems, combined with individual flow compensation, can allow a single ventilator to support more than one patient while maintaining patient-specific control. This challenges the assumption that each patient must always require a dedicated device and highlights opportunities for future ventilator designs based on shared infrastructure.

Rather than increasing capacity by purchasing additional standalone ventilators, multi-patient platforms could improve utilisation of existing technical resources. Core components, including processing hardware, displays, alarms, and power systems, could support multiple treatment channels within a single system. This approach may help optimise equipment use, avoid unnecessary manufacturing, and extend the value of existing infrastructure. Successful implementation would require robust safety mechanisms, clinical validation, and appropriate protocols to ensure that shared systems maintain the required level of patient care.

Benefits of Rethinking

Higher use of existing ventilator capacity

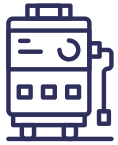
Lower material and component demand

Smaller equipment fleets

Less waste at end of life

Key Take-Away

Shared-use medical devices can deliver equivalent clinical functions with fewer platforms, improving resource efficiency while maintaining safe and effective care.



Sharing Portable Infusion Pumps

Portable infusion pumps enable controlled medication delivery and flexible patient care across healthcare settings. Sharing these devices between departments or patients can improve utilisation, maximise existing equipment capacity, and reduce the need for additional purchases by ensuring available resources are used more efficiently.

Good intention

Share portable infusion pumps to maximise equipment utilisation, avoid unnecessary purchases, and improve resource efficiency across healthcare facilities. Increasing device sharing aims to ensure that existing equipment is used more effectively, reducing the need for additional devices and supporting more efficient allocation of healthcare resources. By allowing multiple departments or care areas to access the same equipment, hospitals can potentially lower procurement needs, optimise inventory management, and make better use of existing infrastructure while maintaining appropriate patient care.

Bad consequence

Frequent movement of shared infusion pumps can create additional logistical demands, including transport, cleaning, disinfection, maintenance, and equipment handling. These processes require staff time, energy, and consumable materials, which may increase the overall environmental impact despite purchasing fewer devices. Increased handling can also contribute to faster wear, additional repairs, and shorter equipment lifespans. If transport and cleaning requirements become excessive, the environmental benefits of device sharing may be reduced or eliminated. A full lifecycle assessment is therefore needed before assuming that shared equipment always provides a more sustainable solution.

Why the habit backfires

- **Transport between departments increases operational requirements and associated resource use.**
- **More frequent cleaning and disinfection can increase consumption of water, energy, and cleaning products.**
- **High utilisation rates may accelerate wear and maintenance needs, shortening device lifespan.**
- **Local availability needs may require additional buffer equipment, limiting expected savings.**

Key Take-Away

Sharing devices is not always more sustainable. Equipment strategies should consider the full lifecycle impact, including transport, cleaning, and maintenance requirements.

Reduce ④ Example 1

Page 21

Insulin Pump

Modern insulin pumps provide continuous insulin delivery through basal rates and bolus dosing. Many systems now include advanced features such as connectivity, glucose monitoring integration, automated dosing, and smartphone interfaces. For users with stable diabetes management needs, simpler devices may provide the required clinical function with fewer resources.

Why we recommend to Reduce

Additional insulin pump features can improve convenience and data access, but they are not always necessary for achieving effective diabetes management. For many users with stable treatment needs, essential basal and bolus insulin delivery may provide the required clinical function without the added complexity of advanced digital features.

Each additional function increases the number of components required, including sensors, processors, communication modules, batteries, and software systems. These additions contribute to greater material use, more energy-intensive manufacturing processes, and increased environmental impacts throughout the device lifecycle. They may also create additional maintenance requirements, software dependencies, and shorter replacement cycles as technology evolves. Reducing device complexity does not mean reducing clinical effectiveness. A simplified insulin pump design focused on essential therapeutic functions can maintain safe and reliable insulin delivery while decreasing unnecessary resource consumption.

By prioritising essential functions over unnecessary complexity, manufacturers can create insulin pumps that better balance patient needs with environmental sustainability. Designing devices that are appropriately complex—not maximally complex—supports efficient healthcare delivery while reducing avoidable material, energy, and waste impacts.

Benefits of Rethinking

Fewer electronic components

Lower material footprint

Longer device lifespan

Less digital dependency

Key Take-Away

Simpler insulin pumps can maintain effective care while reducing resource use, complexity, and environmental impacts from unnecessary features.

Reusable Cataract Surgical Tip

Cataract surgery commonly uses phacoemulsification tips that contact intraocular tissue and require strict sterility. Reusable designs were explored to reduce single-use waste, but achieving repeated sterilization increased material complexity, device requirements, and cleaning demands, creating additional environmental considerations.

Good intention

The intention behind a reusable phacoemulsification tip is to reduce single-use waste generated in high-volume cataract surgery. By creating a component that can withstand repeated sterilization and reprocessing cycles, the goal is to extend device lifespan and reduce the demand for new disposable instruments. Reusable designs aim to lower material consumption, decrease waste generation, and improve resource efficiency by allowing the same device to support multiple procedures. This approach reflects a broader sustainability strategy of replacing disposable products with durable alternatives where repeated use can be achieved safely and efficiently.

Bad consequence

The complexity required to make the tip compatible with repeated sterilization increased its manufacturing footprint. Additional material requirements, specialised design features, and stricter production processes may offset the environmental benefits of reuse. Furthermore, each sterilization cycle requires energy, water, and chemical resources, adding operational impacts throughout the device lifecycle. This demonstrates that replacing single-use devices with reusable versions requires careful lifecycle assessment to ensure that sustainability gains are actually achieved.

Why the complexity backfired

- **Repeated sterilization requires more advanced materials and precise manufacturing, increasing the production footprint before the device is used for the first time.**
- **Each reuse requires a complete sterilization cycle, and over many procedures, cumulative energy, water, and chemical use can exceed the material savings from avoiding disposables.**
- **Repeated processing can accelerate device wear, shortening the usable lifespan and reducing the expected environmental benefits of reuse.**

Key Take-Away

Reusable is not always more sustainable; complex sterilization requirements can outweigh the waste avoided by replacing disposable devices.

Reduce ④ Example 2

Page 21

Smart Pillbox

Smart pillboxes support medication adherence through reminders, notifications, and automated dispensing functions. Many designs include additional protective materials, such as foam inserts, plastic trays, and reinforced structures, to protect electronic components during transport and storage. These materials may exceed what is required for safe and effective operation.

Why we recommend to Reduce

Smart pillboxes often include protective packaging and internal structures to pre-vent damage during transport and handling. While some protection is necessary for safety and reliability, excessive materials may be added without contributing to the device's core function of storing and dispensing medication.

Foam inserts, plastic supports, and multi-layer packaging increase material use, manufacturing impacts, and waste while making recycling and end-of-life man-agement more difficult. A streamlined design using only essential materials for protection, functionality, and durability can maintain performance while reducing environmental impacts.

Material reduction should be considered during the design phase, where manu-facturers can prevent avoidable resource use. By prioritising efficient designs over unnecessary protection, smart pillboxes can support medication adherence while reducing plastic consumption, production demands, and disposal impacts. Sustain-ability improvements can often be achieved through simpler, more resource-effi-cient designs rather than additional technology.

Benefits of Rethinking

Less plastic and packaging material

Lower manufacturing footprint

Reduced transport impacts

Simpler end-of-life processing

Key Take-Away

Reducing unnecessary materials allows smart pillboxes to maintain functionality while lowering resource use, waste, and environmental impact.

Using Safety Gloves for Low-Risk Tasks

Medical gloves are essential when there is contact with blood, bodily fluids, open wounds, or sterile environments. However, their use has expanded into routine care activities where guidelines indicate that proper hand hygiene can provide equivalent protection for patients and healthcare professionals.

Good intention

Use gloves during all patient interactions as a precautionary measure to protect patients and healthcare workers from potential infection transmission. This approach aims to prevent the spread of microorganisms through contact with patients, bodily fluids, contaminated surfaces, or medical environments. Universal glove use is often perceived as an additional safety measure that reduces exposure risks and provides reassurance to both healthcare professionals and patients. By applying the same protective measure consistently across all interactions, organisations aim to strengthen infection prevention practices and minimise the possibility of contamination during routine care activities.

Bad consequence

When gloves are used in situations where hand hygiene alone is clinically sufficient, they create unnecessary single-use waste without improving patient outcomes. High-volume glove consumption increases demand for raw materials, manufacturing processes, packaging, transportation, and disposal. In addition, relying on gloves for low-risk activities may unintentionally reduce attention to proper hand hygiene practices, which remain essential for infection prevention. Using gloves only when clinically indicated maintains patient safety while avoiding unnecessary material consumption and waste generation across healthcare systems.

Why the habit backfires

- **Medical gloves are among the most frequently used disposable products in healthcare. Reducing unnecessary use can therefore generate substantial material savings at scale.**
- **For many low-risk tasks, appropriate hand hygiene provides equivalent protection without the additional material consumption associated with gloves.**
- **Overuse of gloves may create a false sense of security and unintentionally reduce attention to hand hygiene practices, increasing rather than reducing contamination risks.**

Key Take-Away

More protection does not always require more material. Using gloves only when clinically indicated reduces waste while maintaining safe patient care.

Reduce ④ Example 3

Page 21

Water in Endoscopy Cleaning

Endoscopes used for diagnostic and surgical internal visualisation are medium to medium-high-risk devices requiring thorough cleaning and disinfection between uses. Automated reprocessing systems consume significant amounts of water, detergents, and disinfectants through multiple cleaning stages. Standardised cycles may use more resources than necessary for routine reprocessing scenarios.

Why we recommend to Reduce

Water and chemical resources are consumed throughout the endoscope reprocessing cycle, especially during repeated rinsing, cleaning, and disinfection steps. While conservative protocols help ensure reliable decontamination, they may use more water, detergents, and disinfectants than necessary for routine clinical situations.

Evidence-based cleaning thresholds and precise dosing strategies can optimise reprocessing while maintaining infection prevention standards and patient safety. Adjusting rinse volumes, detergent concentrations, and disinfection requirements based on validated performance criteria can reduce unnecessary resource consumption without compromising cleaning effectiveness.

Reducing water and chemical use also supports sustainability by lowering energy demands for treatment, heating, and waste processing. More efficient reprocessing can help preserve device integrity, reduce material degradation, and extend equipment lifespan. By achieving the required safety level without excessive resource use, healthcare systems can maintain high infection control standards while improving environmental performance and reducing avoidable replacement needs.

Benefits of Reducing

Lower water consumption per cleaning cycle

Reduced use of detergents and disinfectants

Less wastewater requiring treatment

Extended lifespan of product and sensitive components

Key Take-Away

Effective decontamination, not maximum resource use, ensures safety. Evidence-based reprocessing lowers environmental impact while maintaining hygiene standards and extending device lifespan.

Full Instrument Set Opened by Habit

Surgical instruments are commonly prepared in standardised trays containing all items that may be required during a procedure. While this supports readiness and efficiency, many operations follow predictable workflows where only a portion of instruments are used, resulting in unnecessary sterilization, packaging, and waste.

Good intention

Ensure procedural readiness and maintain surgical efficiency by providing all potentially required instruments at the start of every procedure. Opening a complete tray allows surgical teams to respond immediately to unexpected needs, reducing delays and avoiding interruptions. Standardised instrument sets are designed to support reliability, simplify preparation, and ensure that essential tools are available whenever required. This approach prioritises patient safety by reducing the risk of missing instruments during complex procedures and creating a consistent workflow across operating rooms.

Bad consequence

Opening full instrument trays creates resource use for items that may never be used. Once opened, all instruments require sterilization, repackaging, and handling, even when they do not come into contact with the patient. Some unused instruments may be discarded due to contamination protocols, expiration limits, or administrative practices. This generates unnecessary waste while consuming water, energy, packaging materials, and sterilization resources. Preparing larger-than-needed sets can therefore increase the environmental footprint of surgery without providing additional clinical value when procedures follow predictable workflows.

Why the habit backfires

- **Sterilization requires water, energy, and chemicals. Processing unused instruments consumes resources without improving patient care.**
- **Many studies show that a large proportion of tray instruments remain unused during routine procedures.**
- **Repeated sterilization cycles wear down instruments over time, shortening lifespan and increasing replacement needs.**

Key Take-Away

Procedural readiness does not require opening every package. Tailoring trays to clinical needs reduces resource use while maintaining safety, quality, and efficiency.

Example of Low Criticality, Session-Based Use Consumable

Page 26

Paper ECG electrodes

Paper ECG electrodes are adhesive, single-use devices that capture cardiac signals during ECG monitoring. Although inexpensive and discarded after one session, their widespread healthcare use creates significant cumulative environmental impacts through material consumption, manufacturing, transportation, and disposal.

Circular Opportunities

Low-cost, session-based consumables such as paper ECG electrodes offer limited opportunities for repair, refurbishment, or remanufacturing. Their single-use de-sign, low value, and hygiene requirements make collection and reprocessing eco-nomically and environmentally impractical. Therefore, extending electrode lifespan is generally not a feasible circular strategy.

Instead, circular opportunities focus on reducing material use and improving re-source efficiency. Manufacturers can optimise electrode design, reduce material thickness where clinically acceptable, incorporate recycled or bio-based mate-rials in non-critical components, and minimise production waste and packaging throughout the lifecycle.

Further improvements can be achieved by considering the broader ECG monitoring system. Extending the lifespan of reusable components, such as lead wires, con-nectors, and monitors, reduces the environmental impact per session. Better waste segregation and recycling of uncontaminated materials can also improve end-of-life management. Although used electrodes typically require clinical waste dispos-al, these upstream and system-level strategies provide practical ways to reduce the overall environmental impact of high-volume electrode use.

Top 3 Recommended Circular Strategies

6 **Repair**

Repair is generally not applicable to the electrode itself. However, reusable components such as lead wires and connectors should be maintained and repaired rather than replaced when damaged

7 **Reuse**

Where clinically appropriate, reusable electrode systems with replaceable contact interfaces can reduce reliance on fully disposable patches while maintaining clinical performance and infection prevention requirements.

11 **Recycle**

The combination of adhesive, conductive gel, and mixed materials limits conventional recycling options. Selecting electrodes with improved material compatibility or implementing take-back schemes can support more effective end-of-life processing.

Key Take-Away

Low-cost consumables can create significant impacts at scale. Optimising reuse, materials, and end-of-life pathways reduces the life-cycle footprint of devices.

Example of Low Criticality, Session-Based Use Capital Equipment

Page 26

Ultrasound machine

Ultrasound machines are high-cost diagnostic devices used for short patient examinations across multiple departments. Despite brief use periods, their high purchase value, durable construction, and repair potential make them suitable for sharing, refurbishment, maintenance, and lifecycle extension strategies.

Circular Opportunities

Ultrasound machines represent a strong opportunity for circular economy approaches due to their high value, long technical lifespan, and relatively low criticality during individual use sessions. Unlike disposable medical devices, these systems are designed for repeated operation over many years, making repair, refurbishment, and reuse economically and environmentally beneficial.

Although ultrasound machines are expensive assets, they are often replaced due to technological upgrades, software limitations, or individual component failures rather than complete functional obsolescence. Many issues, including damaged housings, worn wheels, battery degradation, display faults, and electronic component failures, can be repaired or replaced. Extending equipment lifetimes reduces demand for new manufacturing and avoids unnecessary environmental impacts associated with material extraction and production.

Because ultrasound examinations are typically short and devices are not continuously used, shared ownership models between departments or healthcare facilities can improve utilization rates. Refurbishment and upgrading programmes can further maintain performance while extending operational lifetimes. At end of life, responsible recycling can recover valuable materials such as metals, electronics, and plastics.

Top 3 Recommended Circular Strategies

6 **Repair**
Component failures such as damaged displays, batteries, wheels, and electronic modules can often be repaired, making replacement unnecessary.

7 **Reuse**
Ultrasound machines can be shared across departments or healthcare facilities, increasing utilization of high-value equipment that is only needed intermittently.

8 **Refurbish**
Older machines can be upgraded, restored, and maintained to extend their useful life while avoiding premature replacement of valuable equipment.

Key Take-Away

High-value ultrasound machines are ideal for circular strategies through sharing, refurbishment, and repair to extend lifetimes and reduce impacts.

Example of Low Criticality, Continuous Use Consumable

Page 26

Skin Temperature Patch

Skin temperature patches are low-cost wearable devices designed for continuous physiological monitoring over several days. Although individual devices have limited value and are often disposable, their large-scale use creates significant opportunities for improved material efficiency, component reuse, and end-of-life management.

Circular Opportunities

Skin temperature patches present a different circular challenge compared with high-value medical equipment. Their low cost, direct skin contact, and disposable design make repair and full-device refurbishment economically difficult. However, their continuous-use profile means that large quantities are consumed across hospitals, home care, and remote monitoring settings, resulting in a substantial cumulative environmental footprint.

The most relevant circular opportunities focus on maintaining reliability during use, reducing material demand, and separating valuable components from disposable elements. Improving durability of sensors, electronics, batteries, and wireless communication modules can reduce premature failures and unnecessary replacement during monitoring periods. Product designs that separate reusable electronic components from single-use adhesive interfaces could enable partial reuse while maintaining hygiene requirements.

Functional components such as sensors, communication modules, and batteries could potentially be redirected to lower-risk applications, training environments, or research activities after clinical use. At end of life, improved design for disassembly and recycling can support recovery of electronics, plastics, and battery materials. Given the high volumes involved, even small improvements per device can create meaningful environmental benefits across healthcare systems.

Top 3 Recommended Circular Strategies

5 **Maintain**

Designing durable sensors, reliable electronics, and stable wireless connections helps maximise device performance and prevents premature replacement during monitoring periods.

7 **Reuse**

Where hygiene requirements allow, reusable electronic modules can be separated from disposable adhesive layers and used with new patient-contact interfaces.

11 **Recycle**

Designing patches for easier separation of electronics, batteries, adhesives, and plastics improves material recovery and reduces waste from high-volume use.Key takeaway

Key Take-Away

Low-cost monitoring devices require scalable circular solutions, where component reuse, durability, and recycling create impact through large volumes.

Example of Low Criticality, Continuous Use Capital Equipment

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Hospital Patient Bed

Paper ECG electrodes are adhesive, single-use consumables applied to the skin to capture cardiac electrical signals during ECG monitoring. Each electrode is low-cost, used for a single patient session lasting minutes to hours, and discarded after use. While individual electrodes have limited impact, the high volumes used across healthcare create significant cumulative life-cycle impacts through materials, manufacturing, and disposal.

Circular Opportunities

Hospital beds represent a strong circular economy opportunity due to their high acquisition value, long service life, and continuous use. Unlike disposable medical products, beds are designed as durable systems containing mechanical structures, electric actuators, control electronics, batteries, sensors, and safety features that can be maintained, repaired, and upgraded over time.

Their relatively modular design enables healthcare organisations to perform scheduled maintenance, replace individual components, and refurbish equipment without unnecessary replacement. Repairs can often be limited to specific parts, such as actuators, wheels, brakes, control panels, batteries, or power supplies. Refurbishment programmes can restore worn beds and extend their operational lifespan.

When beds are no longer suitable for acute care, they can be redeployed to rehabilitation centres, long-term care facilities, training environments, or humanitarian healthcare settings. At end of life, design for disassembly and responsible recycling can support the recovery of valuable materials, including steel, aluminium, copper, plastics, and electronic components, contributing to a more circular healthcare system.

Top 3 Recommended Circular Strategies

5 **Maintain**
Preventative maintenance, cleaning, inspection, and battery checks help maximise reliability and extend the operational lifetime of hospital beds.

6 **Repair**
Replacing individual components such as actuators, wheels, electronics, and control systems is economically attractive due to the high value of the asset.

8 **Refurbish**
Restoring and upgrading used beds allows continued safe operation while delaying replacement and reducing demand for new equipment.

Key Take-Away

High-value hospital beds enable strong circular strategies through maintenance, repair, refurbishment, and redeployment across multiple healthcare settings.

Example of High Criticality, Session-Based Use Consumable

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Surgical Stapler

Surgical staplers are high-criticality devices used during surgical procedures to cut, reconnect, and seal tissues. While some models are single-use and others include reusable components, their clinical importance, contamination risks, and strict performance requirements strongly influence circular opportunities.

Circular Opportunities

Surgical staplers represent a challenging category for circularity because they are used in critical surgical procedures where reliability, sterility, and mechanical performance are essential. Direct tissue contact and contamination risks restrict repair, refurbishment, and reuse of components exposed to the surgical field. As a result, many stapler systems rely on disposable elements, creating material waste despite the presence of valuable components.

The strongest circular opportunities focus on separating high-value reusable components from single-use sterile parts. Reusable stapler systems can retain durable mechanical or electronic assemblies, such as handles, while replacing only patient-contact components. This approach reduces material consumption while maintaining the safety requirements associated with surgical applications. Regular inspection, maintenance, and replacement of wear-sensitive parts can further extend the lifetime of reusable components.

At end of life, improved material recovery can reduce the loss of valuable resources. Surgical staplers typically contain metals, plastics, and sometimes electronic components, but mixed-material construction and clinical waste classification create barriers to recycling. Designing for disassembly, improving waste segregation, and introducing recyclable or bio-based materials can support future circular solutions while maintaining required surgical performance.

Top 3 Recommended Circular Strategies

5 **Maintain**

Preventative maintenance, calibration, and replacement of worn parts help preserve safety, reliability, and performance throughout the lifetime of reusable stapler components.

7 **Reuse**

Reusable stapler systems allow high-value components, such as handles and mechanical assemblies, to be sterilised, inspected, and reused across multiple procedures while replacing only sterile components.

11 **Recycle**

Designing staplers for easier disassembly and improving waste segregation can enable recovery of metals, plastics, and electronic components currently lost through clinical waste streams.

Key Take-Away

High-criticality surgical staplers require safety-focused circular strategies, prioritising reusable components, maintenance, and improved material recovery.

Example of High Criticality, Session-Based Use Capital Equipment

Page 27

Cardiopulmonary Bypass Machine (Heart-Lung Machine)

Cardiopulmonary bypass machines are high-value, critical medical systems used during open-heart surgery to temporarily replace heart and lung function. Their high cost, modular design, and long operational lifespan make them strong candidates for maintenance, repair, refurbishment, remanufacturing, and lifecycle extension strategies.

Circular Opportunities

Cardiopulmonary bypass machines represent one of the strongest opportunities for circularity in healthcare due to their high value, technical durability, and modular construction. These systems are designed for repeated use and contain multiple replaceable components, including pumps, heat exchangers, control systems, and monitoring equipment. Their critical role requires strict reliability and safety standards, but also supports structured maintenance and lifecycle management.

Preventative maintenance is already an essential part of heart-lung machine operation, including inspection, calibration, cleaning, and replacement of wear-sensitive components. Further opportunities exist through condition-based monitoring and predictive maintenance, allowing interventions to occur based on actual component performance rather than fixed schedules. This can extend component lifetimes, reduce unnecessary replacements, and improve equipment availability.

Because these systems have substantial remaining value after initial use, repair, refurbishment, and remanufacturing are highly viable strategies. Individual components can be replaced without discarding the complete machine, while certified refurbishment programmes can restore used systems to reliable operating conditions at lower cost than new equipment. At end of life, material recovery from metals, electronics, and plastics can further reduce waste. Components that are no longer suitable for clinical use may also be repurposed for training, research, or simulation environments.

Top 3 Recommended Circular Strategies

5 **Maintain**

Advanced maintenance programmes, including predictive monitoring and condition-based servicing, can maximise reliability, prevent premature replacement, and extend operational life.

6 **Repair**

Modular components such as pumps, electronics, tubing systems, and control units can be replaced individually, maintaining functionality without replacing the complete device.

8 **Refurbish**

Used heart-lung machines can be restored through cleaning, testing, component replacement, and recertification, extending equipment lifetime while providing a lower-cost alternative to new systems.

Key Take-Away

High-value critical devices like heart-lung machines demonstrate strong circular potential through maintenance, repair, refurbishment, and remanufacturing.

Example of High Criticality, Continuous Use Consumable

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Reusable EEG Cup Electrodes

Reusable EEG cup electrodes are low-cost clinical accessories used for continuous neurological monitoring in intensive care and neurophysiology settings. Although individually inexpensive, their direct role in signal acquisition makes hygiene, reliability, and performance critical. Their reusable design creates opportunities for maintenance, reuse, and lifecycle extension.

Circular Opportunities

Reusable EEG cup electrodes demonstrate how low-cost medical accessories can support circular strategies when durability and reprocessing are prioritised. Although individual electrodes have limited value, their frequent use in neurological monitoring can create significant cumulative environmental impacts through material consumption, waste generation, and repeated procurement.

Compared with disposable alternatives, reusable systems can reduce these impacts by extending product lifetimes.
Because EEG electrodes directly contact patients and influence signal acquisition, hygiene, reliability, and performance remain essential. Effective cleaning, disinfection, and inspection procedures are therefore critical to maintaining safety and preventing premature replacement. Durable materials, resistance to repeated cleaning cycles, standardised maintenance protocols, and wear indicators can further extend electrode lifetime while preserving clinical performance.

The main circular opportunities focus on reuse, maintenance, and component-level replacement. Damaged cables, connectors, or electrode mounts can often be replaced individually instead of discarding complete sets. At end of life, materials such as silver/silver chloride contacts, stainless steel, and copper wiring can be recovered through recycling. Electrodes no longer suitable for clinical use may also retain value in training, simulation, or educational applications.

Top 3 Recommended Circular Strategies

5 **Maintain**
Standardised cleaning procedures, durable materials, and inspection protocols help preserve signal quality and prevent unnecessary replacement of functional electrodes.

6 **Repair**
Replacing damaged cables, connectors, or mounting components allows electrode sets to remain operational without discarding the complete system.

7 **Reuse**
Reusable EEG cup electrodes can be cleaned, disinfected, and used across multiple patients, reducing waste compared with single-use electrode systems while maintaining clinical performance.

Key Take-Away

Reusable EEG electrodes show that even low-cost critical accessories can achieve circularity through reuse, maintenance, and component replacement.

Example of High Criticality, Continuous Use Capital Equipment

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Mechanical Ventilator

Mechanical ventilators are high-value, life-critical devices designed for continuous operation while providing essential respiratory support. Their complex technology, long service potential, and high acquisition cost create strong opportunities for maintenance, repair, refurbishment, and lifecycle extension, while strict safety requirements must always be maintained.

Circular Opportunities

Mechanical ventilators represent a challenging but valuable opportunity for circular healthcare strategies. These high-value devices contain advanced sensors, software, electronics, pneumatic systems, and safety mechanisms that require reliable performance throughout their operational life. While their value creates strong incentives to extend use, clinical risks and regulatory requirements influence how circular strategies can be implemented.

Device replacement is often driven by software obsolescence, limited manufacturer support, and risk management considerations rather than complete technical failure. Extending ventilator lifetimes through structured maintenance, software updates, component-level repair, and refurbishment can therefore preserve functional value while maintaining safety and compliance.

The main circular opportunities focus on preventative maintenance, repair, refurbishment, and controlled redeployment. Components such as sensors, displays, valves, and electronic modules can often be replaced individually instead of discarding complete systems. Refurbishment programmes can restore older ventilators through component replacement, software upgrades, testing, and certification. At end of life, design for disassembly can improve recovery of metals, electronics, and engineered plastics, while retired devices may still support training, simulation, or educational activities.

Top 3 Recommended Circular Strategies

5 **Maintain**

Preventative maintenance, calibration, software updates, and system inspections preserve reliability, reduce downtime, and maximise operational lifetime.

6 **Repair**

Component-level repair of sensors, valves, displays, and electronics avoids unnecessary replacement of high-value equipment and reduces material waste.

8 **Refurbish**

Older ventilators can be restored through component replacement, software upgrades, testing, and recertification to extend safe clinical use.

Key Take-Away

High-value life-critical devices offer strong circular potential, but all interventions must preserve safety, reliability, and regulatory compliance.

Example System Design Ideas

System design considerations for a circular smart pillbox

To sustainably innovate a device, the system also needs to become circular. Circular system considerations are used to explore how products, processes, and stakeholders interact throughout product life cycle stages. In this example, we use the smart pillbox to explain circular strategies and system considerations surrounding the device in a circular system.

Use

A smart pillbox is used at home for supporting medication adherence. The pillbox is purchased by the user themselves, or offered through their healthcare provider. The medication schedule is configured by healthcare professionals and synchronized through the pharmacy. Through electronic features such as reminders, notifications, and dispensing mechanisms, the pillbox offers the user automated administration of their medication. This assists the user in taking the right medication at the right time.

5 Maintain

To keep the pillbox functional and preserve quality, the user needs to maintain it properly. To enable the user to perform maintenance activities, such as cleaning and changing batteries, an accompanying app offers them instructions. The app also logs the device's condition within a digital passport, a standardized record that tracks an individual product's life cycle. This allows service providers to monitor the condition of a pillbox, so they know if the product is maintained well, if performance complies with regulatory standards, or if repair is needed.

6 Repair

When the pillbox is functioning beyond maintenance fixability, or use has been completed, the user returns it to a collection point within their local healthcare system: in this case the pharmacy. Clear return pathways, such as an accessible, well-communicated network of designated return locations, are needed to ensure devices are returned efficiently rather than discarded through household waste. Return incentives stimulate users to bring back their devices. This could be a financial deposit, a scannable code, or a guiding visual on the pillbox.

At the pharmacy, the condition of the pillbox is assessed and communicated to the user. They are given advice on maintenance, a replacement product if their current one is too defective, or if on-site repair is possible, a pick-up time for their pillbox. During repair, minor defects are restored, faulty parts are replaced, and the product is cleaned. Repair activities require dedicated workspaces, trained personnel, standardized repair procedures, and access to replacement parts supplied by the manufacturer. Quality checks are standardized, with results recorded within digital passports, compared with regulations, and deciding on the device's continuation in the system. The goal of repair by the pharmacy is to make pillboxes available for re-use.

7 Reuse

When a pillbox is restored to full functionality and meets regulatory requirements, it can be reused. Before redistribution, patient-specific information is removed, and the device is reconfigured for the next user. If the device returns to the same user, the configuration of their medication schedule is checked. Coordination between pharmacies, healthcare providers, and logistics partners is needed to match available devices with new patients. The service and repair history is logged within the digital passport, and the pillbox continues intended use at (a new) home. The restoration, redistribution, and collection require financial consideration to become economically viable. Examples are product pricing, design for disassembly and easy repair, purchasing availability of individual parts, and financial compensation for returns.

If too defective for repair, the pharmacy collects the devices for further processing at a local sorting facility. Standardized inspection procedures and digital product information support efficient routing decisions, determining whether a device proceeds to refurbishment, remanufacturing, recycling, or renewal.

8 Refurbish

At the manufacturer, discarded pillboxes with value as a whole product are refurbished. They are restored to good working condition through decontamination, upgrades, cosmetic changes, and part replacements. Refurbishment activities require certified facilities, cleaning protocols, and quality assurance procedures to comply with medical device regulations before redistribution. Procedure outcomes are recorded for product traceability, and refurbished products can be marked with an identifiable sign on the product, streamlining identification and differentiation.

9 Remanufacture

Discarded pillboxes with (partly) functional components are used for remanufacturing. Components from multiple returned pillboxes are re-assembled to manufacture as-new products that can continue their intended use. The system requires considerations on component availability, inventory management and production planning. Before returning to users, both refurbished and remanufactured pillboxes need quality control and certification to ensure compliance with regulations before they are repackaged and redistributed. Economic viability can be achieved through producing sufficient product volumes and retaining value through restoration and upgrades. An added benefit of refurbish and remanufacturing is improved insight into which product parts are most vulnerable to failure, allowing the pillbox design to be efficiently upgraded over time, possibly enabling a market advantage.

10 Repurpose

When no longer suitable for medical use, the pillbox can be given new purpose through function adaptation. This can be done by the user at home, through redistribution by the pharmacy, or after collection and screening for alternative applications by the sorting facility. An example of repurposing is using a smart pillbox as a household organizer or a timer. Designing the surrounding system to inspire the user, for instance through a platform in which new uses are shared, can connect the device to new use opportunities that increase the value retained after medical use.

11 Recycle

Efficient recycling depends on collaboration between collection facilities, recyclers, and manufacturers, as well as transport infrastructure to connect them. Discarded product which cannot be recovered for intended use are distributed by the sorting facility to local recycling partners. Here waste is transformed to new raw materials through decontamination, shredding, and molding. The material information stored in the product passport supports efficient sorting, while mono-material components and disassembly improve recycling rates of plastics, electronics, and batteries.

12 Renew

If the pillbox has components made from biobased materials, these can be renewed. Product waste is transformed into base elements, such as carbon or biomass. The system surrounding renew requires disassembly locations and a reprocessing workflow. For a smart pillbox with medical use, there are life cycle concerns when using biobased materials. Regulations on safety, chemical contamination, and durability can limit the application of renewable. Material that is composted or chemically treated, must be transported to specialized locations such as composting plants.

The raw materials recovered from recycling and renewing are quality-checked for application opportunities. Regulatory standards on material quality and certification decide if the recovered material can be reapplied to medical products or used in different products with functional adaptation. Insufficient material performance could reduce product lifetime, economic viability, and future circular opportunities. Sufficient material performance will allow to close the circular loop.

Go back to page 29 System Design Consideration.

Example System Design Ideas

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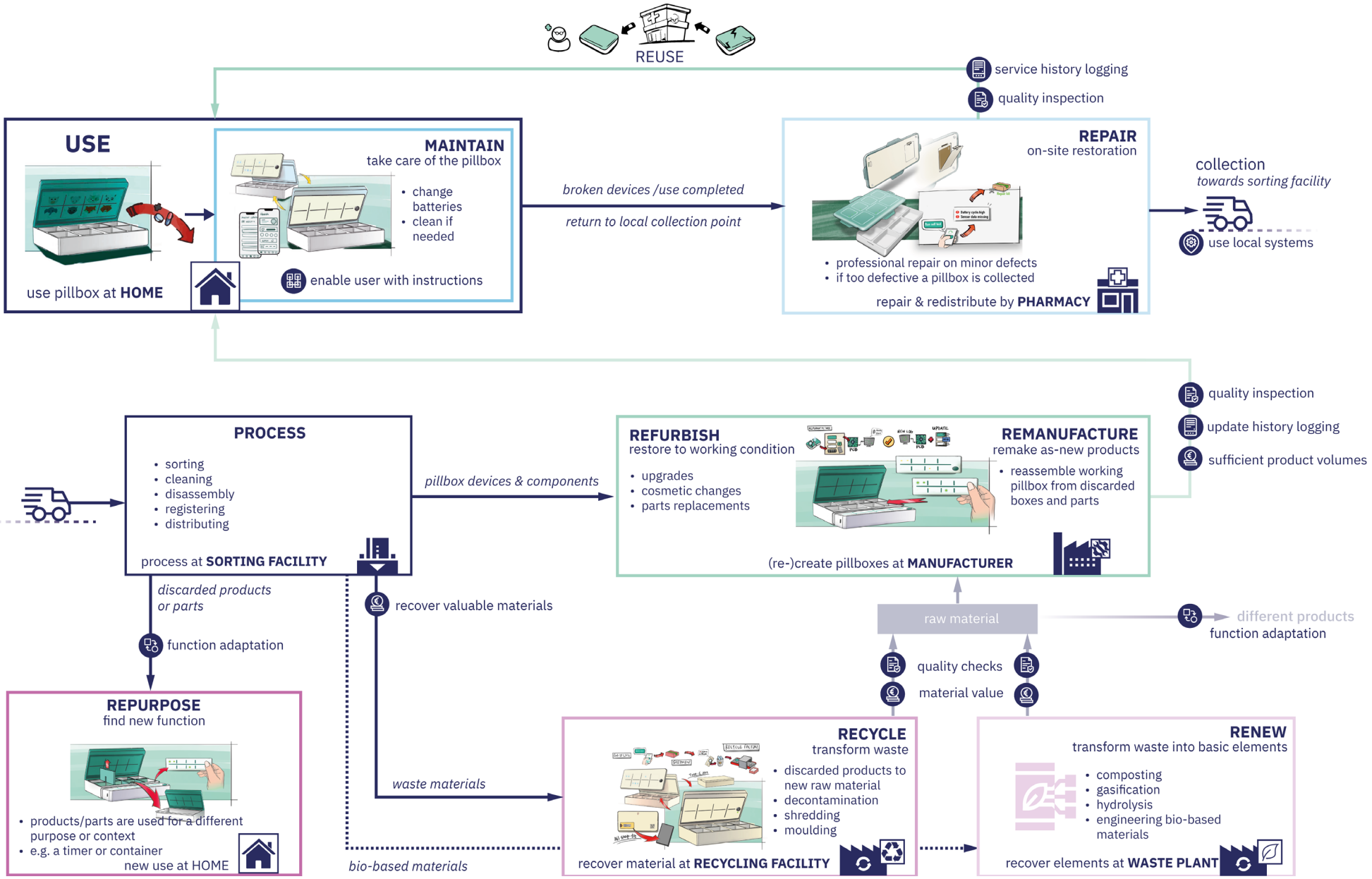

Example Bring-Back Collection Path

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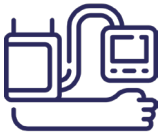

Home Blood Pressure Monitor Returned by Patient

Home blood pressure monitors are used by patients over extended periods and often stored or discarded after use. Without return pathways, devices cannot be captured for refurbishment, remanufacturing, or recycling. Designing convenient return systems can reduce barriers related to accessibility, safety, and data privacy.

What good bring-back looks like

Effective bring-back strategies address the behavioural, practical, and organisational barriers that prevent patients from returning medical devices after use. Many home-use devices remain in households because patients are unsure where to return them, whether their data is protected, or whether returning the device is necessary. A successful return system should therefore be simple, convenient, and clearly integrated into normal device ownership.

Integrating privacy safeguards is essential, particularly for connected devices that store or transmit health information. Clear data removal procedures, secure handling, and transparent communication can increase patient confidence and encourage participation. Logistics should support patient convenience through accessible return points, prepaid shipping options, collection services, or integration with existing healthcare pathways such as pharmacies and care providers.

By combining product design, packaging, and service systems, manufacturers and healthcare organisations can create effective closed-loop pathways for refurbishment, remanufacturing, component recovery, and recycling. A well-designed bring-back system transforms end-of-use behaviour from an optional action into an expected and easy part of the product lifecycle.

Examples of ideas include

- **In the product**
  A clearly marked data reset function enables patients to securely remove stored health data before return, addressing privacy concerns and increasing confidence in participating in device recovery programs.
- **In the packaging**
  The original packaging functions as a return solution, incorporating a prepaid shipping label and clear instructions to minimise patient effort, logistical barriers, and additional material requirements.
- **In the system**
  Automated reminders aligned with the device's expected end-of-use point prompt timely return, reducing dependence on patient recall and improving the likelihood of successful device collection.

Key Take-Away

Successful bring-back requires motivational strategies that make return convenient, secure, and worthwhile by addressing patient barriers through product, packaging, and system design.

Designing for Disassembly

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Designing for disassembly is a product development approach that enables efficient separation of components and materials at the end of a product's use phase. It supports circular strategies such as repair, refurbishment, reuse, and recycling while maintaining the safety, performance, and regulatory requirements expected in medical technology.

Key design considerations include

Minimize material complexity	Use reversible connections	Enable structured disassembly sequences	Address medical requirements
Reduce the number of materials and avoid unnecessary material combinations to simplify separation, improve recycling compatibility, and increase the value of recovered	Select connection methods that enable non-destructive separation, such as screws, snap-fits, and modular interfaces. Minimize permanent connections, such as adhesives or welding, where they limit repair, reuse, or material recovery.	Design components to be accessible and removable in a logical order. Consider disassembly steps, required tools, handling requirements, and the separation of components with different end-of-life pathways.	Integrate contamination control, sterilization requirements, and safety considerations into the disassembly strategy. Ensure that patient-contact components, electronics, and other sensitive parts can be safely handled after use.

Tip: make a disassembly Map

A disassembly map is a visual representation of how a product can be separated into its components and materials. It shows the disassembly sequence, connection methods, material flows, and potential end-of-life pathways.

Disassembly maps are used to:

- **Identify design barriers to repair, reuse, and recycling.**
- **Evaluate the accessibility and reversibility of connections.**
- **Support decisions on material selection and product architecture.**
- **Improve communication between designers, manufacturers, service providers, and recycling partners.**

By integrating disassembly maps early in the design process, medtech companies can improve product circularity while maintaining safety, performance, and regulatory requirements.

Material Choice Guidance

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Material selection in healthcare requires balancing clinical performance, patient safety, regulatory requirements, and opportunities for reuse or recycling at end-of-life.

Examples of Medically Approved Biomaterials

Biobased materials can reduce fossil resource dependency while providing suitable performance for selected healthcare applications.

- Bio-based Polyamide (PA) – Used in medical device components requiring high strength, durability, and chemical resistance, such as surgical instruments and device housings.
- Bio-based Polyethylene (PE) – Used for healthcare products such as containers, packaging, and components requiring lightweight, chemical-resistant materials.
- Bio-based Polypropylene (PP) – Used in medical disposables, laboratory products, and device components due to its low moisture absorption and sterilization compatibility.
- Polylactic Acid (PLA) – Used in medical research applications, biodegradable implants, and temporary devices where controlled degradation is required.
- Polyhydroxyalkanoates (PHA) – Biodegradable polymers investigated for applications such as tissue engineering, drug delivery systems, and temporary medical devices.

Examples of Medically Approved Recyclable Materials

Recyclable medical materials support resource recovery when products are designed for separation, safe handling, and suitable recycling processes.

- Polypropylene (PP) – Widely used in syringes, medical containers, laboratory equipment, and disposable device components; recyclable when properly separated.
- Polyethylene (PE) – Used in medical packaging, tubing, bottles, and containers due to its flexibility and chemical resistance.
- Polycarbonate (PC) – Used in reusable medical equipment, transparent housings, connectors, and protective components requiring impact resistance.
- Polyether Ether Ketone (PEEK) – Used in implants, surgical instruments, and medical components requiring high mechanical and chemical performance.
- Stainless Steel – Used extensively in surgical instruments, implants, and reusable medical devices; highly recyclable through metal recycling streams.
- Titanium – Used for implants, orthopedic devices, and surgical instruments due to its strength, biocompatibility, and corrosion resistance.

Examples of Materials Compatible in Recycling

While separation of materials remains the preferred strategy, selecting compatible materials can simplify recycling and improve recovery rates.

- Polypropylene (PP) + Polyethylene (PE) – Similar polyolefin materials that can sometimes be processed together in recycling streams.
- PET with compatible PET grades – Used in medical packaging and containers; recycling is improved when material composition is consistent.
- Stainless steel alloys – Commonly recycled together in established metal recycling processes.
- Aluminium alloys – Used in medical equipment and components; efficiently recovered through aluminium recycling.
- Mono-material polymer designs – Using a single polymer type simplifies sorting, improves recycling quality, and reduces material contamination.

Designing for material identification and easy separation remains the preferred approach to enable high-quality recycling in healthcare products.

Example In-Hospital Reprocessing Collection Path

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Surgical Intruments

Home blood pressure monitors are used by patients over extended periods and often stored or discarded after use. Without return pathways, devices cannot be captured for refurbishment, remanufacturing, or recycling. Designing convenient return systems can reduce barriers related to accessibility, safety, and data privacy.

What Good In-Hospital-Reprocessing looks like

Effective in-hospital reprocessing depends on a well-organised internal system that enables rapid collection, reliable cleaning, and safe return to clinical use. Because instruments remain within the healthcare facility, hospitals maintain direct control over handling, quality assurance, and turnaround times. This reduces logistical complexity while supporting repeated use of durable medical equipment.

Collection should occur immediately after procedures, with clear separation between reusable instruments and single-use waste. Standardised workflows, staff training, and appropriate tracking systems ensure that instruments are correctly identified, transported, and prepared for reprocessing. Maintaining visibility of instrument location and status can further improve efficiency and reduce losses.

Within central sterile services departments, instruments undergo validated cleaning, disinfection, inspection, and sterilisation processes before being returned to circulation. Regular quality checks, maintenance, and replacement of worn components help preserve functionality and extend service life. By keeping the entire cycle inside the healthcare facility, in-hospital reprocessing creates a reliable circular pathway that reduces material consumption, avoids unnecessary replacement, and maintains clinical safety.

Examples of ideas include

- **In the collection process**

Point-of-use sorting systems ensure reusable instruments are separated immediately after procedures, reducing contamination risks and preventing valuable devices from entering waste streams.

- **In the reprocessing workflow**

Central sterile services can use standardised cleaning, inspection, sterilisation, and tracking protocols to maintain safety while maximising the number of reuse cycles.

- **In the system**

Digital tracking systems provide visibility of instrument location, usage history, and maintenance needs, improving asset management and reducing unnecessary losses.

Key Take-Away

In-hospital reprocessing enables safe reuse by keeping devices within a controlled, efficient, and traceable healthcare loop.

Example Example (Third-Party) Take-Back Collection Path

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Surgical Drill

Surgical drills are high-value, precision instruments used in orthopaedic and neurosurgical procedures. Their complex construction, including motors, gears, electronics, and specialised components, requires expertise beyond typical hospital maintenance capabilities. Manufacturer or third-party take-back programmes enable safe refurbishment and lifecycle extension.

What Good Take-Back Looks Like

Effective take-back systems remove the responsibility and complexity of refurbishment from healthcare facilities by creating a structured pathway between hospitals, manufacturers, and certified service providers. Because surgical drills require specialist knowledge, dedicated tools, and regulatory oversight, centralised refurbishment ensures that devices can be safely restored without compromising clinical performance.

Collection should be simple, predictable, and integrated into existing hospital processes. Scheduled return programmes linked to maintenance intervals, replacement cycles, or equipment upgrades reduce the likelihood that devices are stored, abandoned, or prematurely discarded. Clear logistics, documentation, and communication help hospitals understand when and how equipment should be returned.

During refurbishment, manufacturers or certified third parties can disassemble, clean, inspect, repair, replace worn components, and test surgical drills against original performance requirements. This controlled process allows valuable devices to return to clinical use while maintaining quality standards and regulatory compliance. Refurbished equipment can then be returned to the original healthcare facility or redistributed, reducing demand for new manufacturing and preserving the value embedded in the device.

Examples of ideas include

- **In the collection process**

Scheduled take-back programmes provide hospitals with predefined return pathways, reducing administrative effort and preventing valuable equipment from being stored or discarded.

- **In the recovering process**

Certified reprocessing, refurbishment, and remanufacturing centres restore devices through specialist cleaning, component replacement, testing, and validation to ensure safe performance comparable to new equipment.

- **In the system**

Manufacturer-supported tracking systems monitor device ownership, maintenance history, and return timing, improving visibility and enabling efficient circular flows.

Key Take-Away

Manufacturer take-back enables circularity for complex devices by centralising, e.g., refurbishment, ensuring safety, compliance, and lifecycle extension.

Example Overcoming Financial Constraints

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Medical Imaging Equipment

The barrier

Healthcare organisations may hesitate to adopt longer-life or refurbished medical equipment because of concerns about upfront investment, maintenance responsibility, reliability, and technology obsolescence. These concerns can favour replacement over extending device lifetime.

The adaptation

Circular service models shift the focus from selling equipment to managing device performance throughout its lifecycle. Manufacturers can provide maintenance, upgrades, refurbishment, and take-back services to keep equipment operational for longer. For OEMs, this can create additional revenue streams through lifecycle services while strengthening long-term customer relationships.

Key Take-Away

Circularity can create business value when manufacturers move from selling replacement products towards delivering long-term device performance.

Examples Hybrid, Refill and Sleeve Design

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Hybrid Design

Hybrid Laparoscopic Instrument

The barrier

Laparoscopic surgery requires strict sterility and reliable performance. This often creates a choice between fully disposable instruments, which generate significant waste, and fully reusable instruments, which require complex cleaning, sterilisation, and maintenance processes.

The adaptation

Hybrid (“resposable”) instruments separate the device into reusable and single-use components. High-value elements such as handles, shafts, or electronic components remain in use across multiple procedures, while only the patient-contact component is replaced. This combines the safety advantages of single-use components with the resource benefits of reuse.

Key Take-Away

When sterilisation limits full reuse, hybrid designs retain reusable value while replacing only necessary components.

Refill Design

Refillable autoinjectors

The barrier

Many autoinjectors are designed as single-use devices, meaning the complete mechanical or electronic system is discarded after a brief injection. This leads to unnecessary disposal of durable components that could remain functional across multiple treatments.

The adaptation

Refillable designs separate the reusable drive mechanism and housing from the replaceable drug cartridge. After administration, only the cartridge is replaced, while the main device remains in service for multiple doses. This reduces material use by limiting disposal to the smallest necessary component.

Key Take-Away

When a device is used briefly but contains durable components, separating the reusable mechanism from the consumable can significantly reduce waste.

Sleeve Design

Sleeved Ultrasound Probes

The barrier

Ultrasound probes contain sensitive electronics that may be damaged by repeated sterilisation processes. However, they require protection against cross-contamination between patients, creating pressure towards disposable alternatives.

The adaptation

A disposable sterile sleeve creates a protective barrier between the probe and the patient while allowing the high-value electronic components to remain reusable. This avoids disposal of the complete device while maintaining infection prevention requirements.

Key Take-Away

When direct sterilisation is technically challenging, protective barriers can enable continued use of valuable device components.

Decontamination

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Collect and sort devices by type, condition, classification (non-critical, semi-critical, critical), and next CHF.

Health devices are decontaminated after use in up to four steps, depending on the device type and required level of decontamination. Some need dismantling before cleaning.

1 Pre-Cleaning

Contaminated devices may undergo manual and/or mechanical pre-cleaning (e.g., rinsing, ultrasonic cleaning) to remove visible residues.

2 Cleaning

All devices undergo manual or mechanical cleaning. This removes (in)visible contaminants.

3 Disinfection

Devices that contact skin or mucous membranes (e.g., thermometers, endoscopes) are disinfected manually or mechanically using chemicals and/or heating.
Low-level disinfection removes most bacteria, some viruses, and fungi, while high-level disinfection eliminates nearly all microorganisms except some spores.

4 Sterilisation

Devices that penetrate sterile tissues or the bloodstream (e.g., surgical instruments) must be sterilised.
A device is sterile when the probability of viable microorganisms is less than 1 in a million (SAL).

There are various methods to sterilise a medical device (Steam, EtO, Radiation, H3O3).

The preferred method depends on material properties, the number of devices, the costs, environmental impact and availability).

Glossary

To support a shared understanding and consistent use of terminology throughout this guide, key terms are defined below. Definitions are primarily based on authoritative sources, including EU Directives, the Medical Device Regulation, UNEP, the IAEA, and ISO, with project-specific definitions added where needed. This glossary presents a selection of terms from the broader DiCE glossary, available at: https://circulardigitalhealth.eu/terms-and-definitions/, supplemented with additional definitions developed specifically for this design guide.

Active (medical) device
Any device, the operation of which depends on a source of energy other than that generated by the human body for that purpose, or by gravity, and which acts by changing the density of or converting that energy. Devices intended to transmit energy, substances or other elements between an active device and the patient, without any significant change, shall not be deemed to be active devices. Software shall also be deemed to be an active device.

Benchmarking
Practice of measuring products, services, processes or performance against industry standards or best practices to identify opportunities for improvement.

Bill of materials (BOM)
Comprehensive list of the raw materials, components, assemblies and quantities required to manufacture a product.

Circular flow of resources
Systematic cycling of the provision and use of resources within multiple technical or biological cycles.

Circular health flows strategies (CHFs)
Strategies outlining specific steps for the efficient collection, processing, and safe reintegration of materials, medical products within the healthcare system with the aim of minimizing waste and maximizing resource value. Examples include: refuse, replace, rethink, reduce, maintain, repair, reuse, refurbish, remanufacture, repurpose, recycle, renew, and recover energy — adapted to the specific requirements and safety standards of the healthcare sector.

Circular recovery hierarchy
Structured sequence of prioritized circular health flows strategies (CHFs) for guiding decision-making while minimizing environmental impacts.

Cleaning
Removal of contaminants to the extent necessary for further processing or for intended use.

Clinical benefit
The positive impact of a device on the health of an individual, expressed in terms of a meaningful, measurable, patient-relevant clinical outcome(s), including outcome(s) related to diagnosis, or a positive impact on patient management or public health.

Collection
The gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility.

Decontamination
Process of removing or neutralizing contaminants such as microorganisms from surfaces or devices to prevent infection spread. Examples include (pre-)cleaning, disinfection, and sterilization based on the intended medical application of the device.

Depollution
Selective treatment during which certain substances, mixtures or components that are potentially harmful are safely removed.

Digital Product Passport (DPP) / Digital device passport
Digital record that consolidates essential information on a product's identity, composition, compliance, safety, sustainability and life cycle.

Disassembly
Process whereby a product is taken apart in such a way that it could subsequently be reassembled and made operational.

Disinfection
Process to inactivate viable microorganisms to a level previously specified as being appropriate for a defined purpose.

Disposal
Any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

Ecodesign
The integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle.

End of life (EoL)
The life cycle stage that begins when a product is discarded and ends when the waste material of the product is returned to nature or enters another product's life cycle.

Energy recovery
Use of combustible waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat.

Environmental hotspots
Stages, processes, materials or components within a product life cycle that contribute disproportionately to environmental impacts such as greenhouse gas emissions, resource use, water consumption or waste generation.

Fancy plastics
Plastic materials that may be challenging to separate and recycle due to their unique composition or combination of different plastic types, additives, or coatings.

Hazardous waste
Waste which displays one or more of the hazardous properties listed in Annex III, including 'infectious', which refers to substances and preparations containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.

Infectious waste
Waste that is capable of causing or spreading disease in man or other living organisms as it is containing or suspected to contain viable microorganisms or their toxins, or human pathogenic microbiological agents.

Invasive device
Any device which, in whole or in part, penetrates inside the body, either through a body orifice or through the surface of the body.

Life Cycle Assessment (LCA)
Methodology used to assess the environmental impacts associated with all stages of a product's life cycle, from raw material extraction and production to use and end-of-life treatment.

Manufacturer
A natural or legal person who manufactures or fully refurbishes a device or has a device designed, manufactured or fully refurbished, and markets that device under its name or trademark.

MDR (Medical Device Regulation)
European Union regulatory framework governing the safety, performance, manufacturing and market placement of medical devices within the European Economic Area.

MDR criticality classification
A risk-based system that uses a set of criteria to determine classification of medical devices. It involves considering factors such as the intended use of the device, physical characteristics, part of the body affected by the use of the device, duration of contact with the human body, degree of invasiveness, potential toxicity, and if the device depends on a source of energy. Devices are divided into the following four classes I, IIa, IIb and III, with Class III devices having the highest level of risk and regulatory requirements.

Medical device
Any instrument, apparatus, appliance, software, implant, reagent, material or other article intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the following specific medical purposes:

- diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of, or compensation for, an injury or disability,
- investigation, replacement or modification of the anatomy or of a physiological or pathological process or state,
- providing information by means of in vitro examination of specimens derived from the human body, including organ, blood and tissue donations,

and which does not achieve its principal intended action by pharmacological, immunological or metabolic means, in or on the human body, but which may be assisted in its function by such means.
The following products shall also be deemed to be medical devices:

- devices for the control or support of conception;
- products specifically intended for the cleaning, disinfection or sterilisation of devices as referred to in Article 1(4) and of those referred to in the first paragraph of this point.

Medical incineration
Burning of wastes generated by healthcare facilities, including hospitals, veterinary clinics, and research facilities, for the purpose of disposal.

Medical waste
Waste generated by health care activities, ranging from used needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, medical devices and radioactive materials.

Nudge
Any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives.

Preparing for re-use
Checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

Recovery
Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function.

Reprocessing
A process carried out on a used device in order to allow its safe reuse including cleaning, disinfection, sterilisation and related procedures, as well as testing and restoring the technical and functional safety of the used device.

Reprocessor
(1) 'reprocessor' means the health institution and the external reprocessor reprocessing single-use devices; (2) 'external reprocessor' means the entity reprocessing single-use devices at the request of a health institution; 'reprocessing cycle' means a cycle that includes all reprocessing steps applied to a single-use device to ensure that the safety and performance of the reprocessed device is equivalent to that of the original device.

Reusable medical device
Medical device designated or intended by the medical device manufacturer as suitable for processing and reuse.

Reverse logistics
Activities engaged to recapture the value of products, parts, and materials once they have reached end-of-use or end-of-life.

Separate collection
The collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.

Sharps
Objects or instruments necessary for the exercise of specific healthcare activities, which are able to cut, prick, cause injury and/or infection.

Single-use medical device
Medical device labelled or intended to be used on one individual during a single procedure.

Sterilization
Validated process used to render product free from viable microorganisms.

System
Set of interconnected elements, actors, processes and infrastructures that interact within a broader context to achieve a specific function or purpose.

The Greenhouse Gas (GHG) Protocol
Internationally recognised framework for measuring, managing and reporting greenhouse gas emissions.

Value retention
Strategies aimed at maintaining the functional, economic and material value of products, components and resources for as long as possible through approaches such as reuse, repair, refurbishment and remanufacturing.

Visual taxonomy of circular healthcare flows
Structured visual classification system used to represent and communicate circular resource flows, processes and strategies within healthcare systems.

Waste
Resource that is no longer considered to be an asset as it, at the time, provides insufficient value to the holder.

Looking for the definitions of the circular strategies?

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Let it Flow

Content

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