Sustainable Design for Healthcare Devices: **Pathways Toward Net Zero**

INTRODUCTION

As companies across the pharmaceutical Industry strive to implement sustainability targets, every opportunity for device and system footprint reduction should be explored.

The ultimate goal is full Circularity. In the pursuit of this, many opportunities for sustainability enhancement can be identified for every stage of a device's lifecycle.

This poster works through each of those phases to explore the associated issues, identifying opportunities and design solutions that offer significant improvements to product footprint.

WHAT IS CIRCULARITY?

The Circular Economy represents the Gold Standard of device sustainability, aiming to capture and reuse all finite resources indefinitely whilst minimising negative external effects.

Circularity promotes the remanufacture of products and efficient recycling of materials, demanding that design attention is paid to every stage of the product's lifecycle.

It's not all thankless hard work though – circularity can deliver additional tangible benefits, such as cost saving, efficiency improvements, and increased product reliability.

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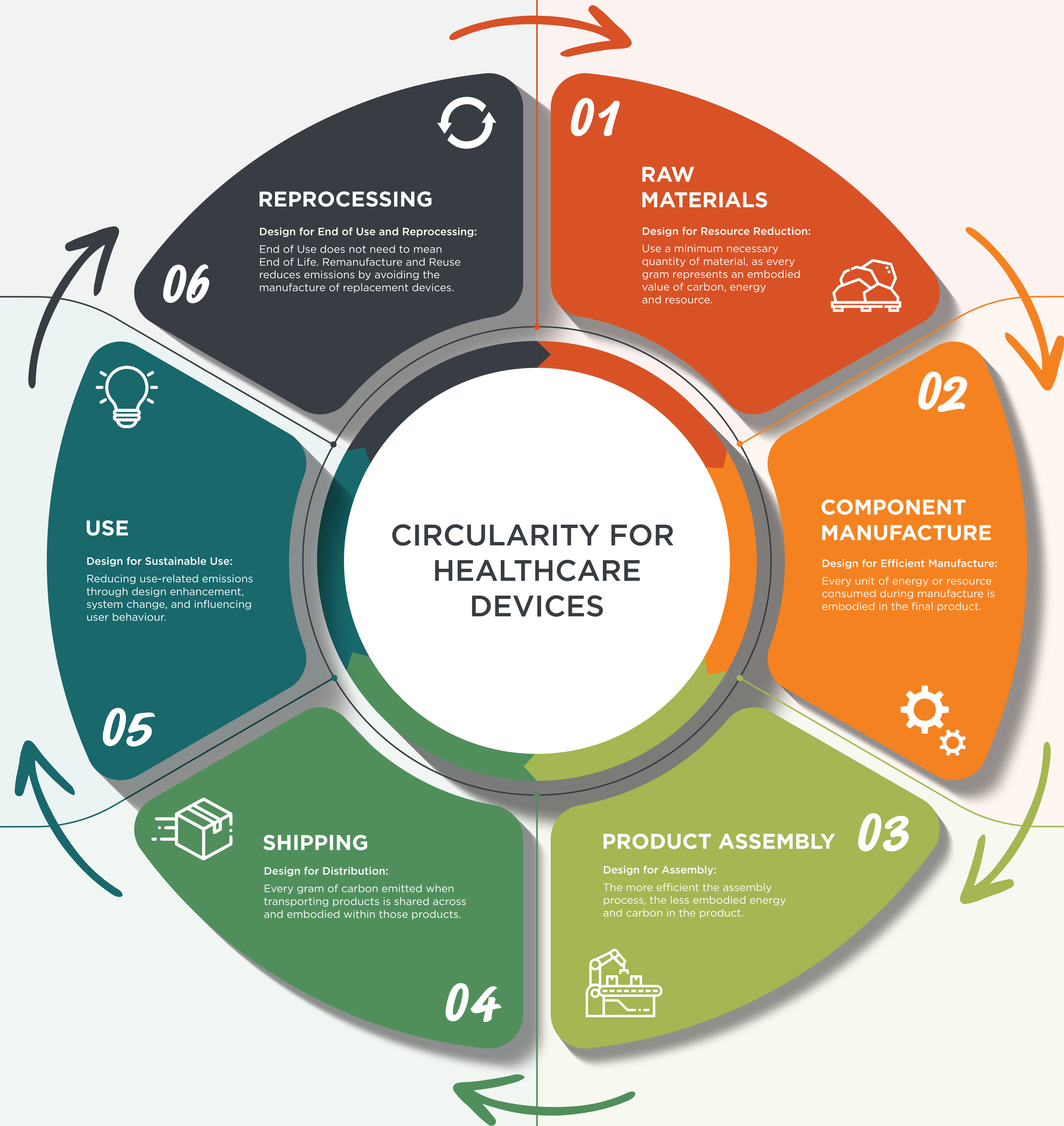
REFERENCES & FURTHER READING

1. UK Government Greenhouse Gas conversion factors 2022
2. Active Disassembly Fasteners collapse under high temperature or pressure to enable rapid product disassembly.
3. DPPs are an EU initiative being rolled out across various industries in which a Digital Twin is a database of lifecycle information for each individual product.
4. Post-Industrial Recyclate (PIR) material streams tend to be more controlled and so better quality than Post-Consumer Recyclate (PCR) streams.

The Ellen MacArthur Foundation: https://www.ellenmacarthurfoundation.org/
UK Government Department for Energy Security and Net Zero: https://www.gov.uk/government/organisations/department-for-energy-security-and-net-zero

HOW TO USE THIS POSTER:

Choose the lifecycle stage you wish to address, and work through the cascade to identify potential solutions.



REPROCESSING

DESIGN FOR RETURN
- Use durable packaging that can be re-used for spent device collection and return.
- Use a specialist courier service to deliver and collect devices.
- User data management systems to track devices, deliver and collect according to prescription schedule or use lifetime.

DESIGN FOR DISASSEMBLY
- Identify key components or sub-assemblies as candidates for re-use, repair or replacement.
- Design Disassembly jigs concurrently with device and Assembly jig design.
- Consider the use of Active Disassembly fastener technology[2].

DESIGN FOR REMANUFACTURE
- Identify key components or modules as candidates for re-use, repair or replacement.
- Digital Product Passports (DPPs) enable Digital Twin device lifecycle tracking[3].
- Mark components with machine-readable IDs for automatic sorting.

DESIGN FOR RECYCLING
- Paper, card and pulp is preferable for single-use packaging as it is renewable, biodegradable, and recyclable.
- Single-use components should be made from materials that are easy to recycle with low degradation, e.g. PP or Aluminium.
- Single-use components or packaging can be returned with the device for disassembly and capture into controlled, closed-loop recycling streams, or as Post-Industrial Recyclate (PIR)[4].

USE

DESIGN FOR CIRCULAR USE
- Use a specialist courier service to deliver and collect devices (in batches).
- User data management systems to track devices, deliver and collect according to prescription schedule or use lifetime.
- Provide durable, reusable packaging to enable easy, intuitive device storage and return.

PHYSICAL DURABILITY
- Emotional Durability promotes physical durability by increasing the emotional value of the product to the user.
- Reliability Is a quantifiable measure of a product's resistance to failure.
- When reliability fails, repairability ensures continued durability.

RESOURCE AND WASTE REDUCTION
- Replace consumable parts with serviceable items, e.g. washable filters.
- Incorporate sterile barriers into the product itself, instead of disposable packaging.
- Minimise other resource requirements during use, e.g. water or cleaning agents.

ENERGY CONSUMPTION
- Use energy efficient components, such as high-quality displays.
- Employ effective thermal management.
- Will a mechanical solution suffice?

SHIPPING

MINIMISE VOLUME AND MASS
- The smaller the packaged product, the more units can be transported per shipment.
- The lower the mass of the packaged product, the less energy & carbon is used transporting it.
- Low product mass should be balanced against robustness and durability requirements.

MODES OF SHIPPING
- For international shipping, the lowest carbon method is by container ship, at 0.016 kg CO_2e per tonne km[1].
- Long-haul air freight, at 1.02 kg CO_2e per tonne km[1], has 100x the impact of container shipping.
- The worst offender, at 2.30 kg CO_2e/T.km[1], is short-haul air freight.

COLD CHAIN SHIPPING
- This reduces the number of products per shipment due to additional insulation volume.
- Consider regional manufacturing for temperature-sensitive medication.
- Devices can be manufactured at a global site, then shipped to a regional plant for filling and local refrigerated distribution.

LAST MILE EMISSIONS
- A Product-as-a-Service business model can utilise a courier to deliver the device directly to the customer.
- The same courier can be used for collection of the device at end of life.

RAW MATERIALS

METALS
- Recycling metal uses far less energy, water and other resources than virgin ore extraction.
- Replacing metals with alternatives such as glass-filled nylon reduces embodied and transport-related carbon.

FOSSIL-BASED POLYMERS
- High-quality grades of recycled-content plastic are now available (PCR, PIR).
- Many polymer grades are available with bio or recycled content to reduce virgin material mass.
- Sustainable Content virgin grades typically use a mass-balance approach.

BIO-BASED POLYMERS
- Bio-polymers may offer significant emissions reductions but should be considered carefully.
- Additional demands may be placed on local resources in feedstock production.
- Compostable materials may produce methane if not composted.

ALTERNATIVES
- Exotic materials such as carbon fiber offer performance improvements but may present end-of-life challenges.
- Consider options such as Paper Injection Moulding (PIM) or Mycelium-based fibre.
- Beware additional resource consumption, e.g. water or land area.

COMPONENT MANUFACTURE

FACILITY POWER
- Choose renewable power supply. Carbon from power generation is embodied in the product.
- Insulate buildings effectively to avoid energy wastage through inefficient climate control.
- Choose electricity over gas for heat-generating equipment

PLASTIC MOULDING
- Minimise part size and complexity - smaller injection mould presses and shorter cycle times consume less energy.
- Gas-Assisted and Induction-Heated moulding technologies offer energy and mass reduction opportunities.
- Family and multi-cavity tools are more efficient than multiple presses.

POST-PROCESSING
- Every post-process operation requires time, floor space and energy.
- Anodising produces toxic waste products, which need treatment.
- Balance negative effects against benefits from increased physical or emotional durability.

ELECTRONICS AND POWER SOURCES
- Rechargeable cells permit extended device lifetimes, and can be recovered and reused.
- Alternative power sources e.g. paper-based batteries, user-powered, USB-powered
- Electronics have 20 times the emissions of plastic parts by mass. Will a mechanical solution suffice?

PRODUCT ASSEMBLY

FACILITY POWER
- Choose renewable power supply. Carbon from power generation is embodied in the product.
- Insulate buildings effectively to avoid energy wastage through inefficient climate control.
- Minimise the use of powered assembly processes, such as ultrasonic welding.

COMPONENT ASSEMBLY METHODS
- Screws, or other mechanical fasteners, can enhance durability, reliability, and repairability.
- Snap fits permit rapid, efficient assembly, with minimal additional fasteners, but be wary of trade-offs.
- Avoid permanent joining of dissimilar materials; e.g. use seals instead of ultrasonic welds.

CONSIDER ASSEMBLY AND DISASSEMBLY TOGETHER
- Assembly jigs and fixtures should be designed concurrently with the device design to ensure maximum assembly efficiency.
- Disassembly methodology should also be incorporated into the device design. This may involve the design of disassembly jigs and fixtures.