6. Products used in surgical care

Section key points

- Circular economy principles can be applied to reduce environmental impact of products, seeking to minimise waste material and energy at all stages of a product's life cycle.
- At the stage of product design, this may be facilitated through adopting the Design for the Environment framework, and applying the principles of Green Engineering, and Green Chemistry.
- Core circular economy concepts which can be applied to healthcare products include refuse, reduce, reuse, recycle, renew (through repair or remanufacture) and recycle.
- Average reductions in carbon footprint of 38–56% are achieved through switching from single-use to reusable equipment.
- There are further opportunities to optimise environmental impact of reprocessing of reusable equipment; for example, through the preparation of instrument sets and by optimising the efficiency of washing and decontamination/sterilisation machines.

6.1 Principles of a circular economy for medical products

Evaluating ways to reduce the carbon footprint of products used in operating theatres will play an important role in the transition to sustainable models of surgical care. Manufacturing and distribution of medical and non-medical supplies, devices, and pharmaceuticals accounts for up to 71% of healthcare's global GHG emissions,[21] in concordance with estimated figures of nearly two-thirds of NHS England's carbon footprint.[22] Also called 'scope 3' emissions, these are beyond the direct control of a healthcare organisation, but can be influenced by healthcare professionals and procurement teams, for example through product selection and use. The principles outlined in this section apply to products used throughout the patient surgical care pathway, by both surgical and anaesthetic teams.

The operating theatre is an area of the hospital with particularly high medical product use and consumption. Surgical products have been associated with up to two-thirds of the carbon footprint of a cataract operation,[294] and a single adenotonsillectomy operation was found to generate over 100 separate single-use plastic items.[295] A number of items used in operating theatres are those with the highest GHGs, including single-use surgical instruments, gloves, surgical caps, drapes, tubing and drains.[296] Single-use products have also been found to be responsible for 68% of the carbon footprint of products used for the five most common operations in England.[297] This issue is increasing, with the global surgical equipment market growing at 9.8% per year, and anticipated to be worth US$24.5 billion by 2028.[298]

Many products have a linear 'life cycle', involving raw material extraction ('cradle'), production, distribution, use, and disposal ('grave'); which is unsustainable given finite planetary resources. By contrast in nature, all life cycles are cyclical, with 'waste' from one animal or biological system feeding another. The volumes of unused materials, such as the plastics filling our landfills, ditches, and oceans,[299] do not exist in natural systems.

Mechanisms to reduce the environmental impact of surgical products may include adopting **circular economy** principles, and developing and using products which are reused and re-engineered, ideally indefinitely. Whilst indefinite reuse is a theoretical concept (no product can be reused indefinitely), the composite elements of the product can be captured and reused in some form, using different processes. Here 'waste' is considered a valuable resource with potential for regeneration via repair, remanufacture, or recycling.[300] The circular economy framework builds on the Cradle to Cradle ideology popularised by Braungart and McDonough, whereby products are used as feedstock for other products at the end of their usable life (rather than Cradle to Grave linear economy, where such products end up as waste with no further use).[301]

The circular economy model maximises material and energy flows, with common principles known as the **5 Rs: Refuse, Reduce, Reuse, Renew and Recycle.**

Refuse

Healthcare professionals and those involved in healthcare procurement should feel able to refuse less sustainable items (for example single-use electrosurgical products)

Reduce

Largest environmental reductions will be associated with absolute reductions (rather than looking at alternative products)

Reuse

For almost all surgical products, opting for reusables is associated with lower environmental impact compared with single-use equivalents[45,193,302]

Renew

There are opportunities to extend the lifespan of healthcare equipment through repairing reusable items, or remanufacture of single-use items (enabling further use)

Recycle

As a last step, recycling enables materials within products to be recaptured and used in the manufacture of other products, preventing materials being lost as waste

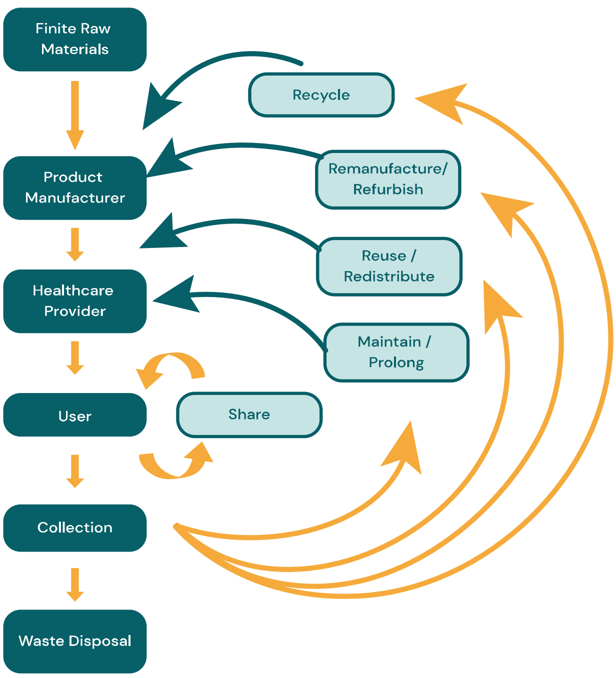
These concepts are considered in more detail in the following sections (6.2–6.7).[303]

CASE STUDY: Improving sustainability of laparoscopic appendectomy

Setting	Leeds Teaching Hospital NHS Trust
Patients	Patients undergoing laparoscopic appendectomy
Interventions	• Switch from single-use to reusable gowns and drapes • Replace single-use instruments with reusable instruments in appendectomy instrument tray
Outcome	↓ 2.6 tonnes CO_2e / year ↓ £10,000 / year

Source: Centre for Sustainable Healthcare[304]

Figure 10: The circular economy



Adapted from Ellen MacArthur Foundation[304]

The diagram above (Figure 10) illustrates that most value (and carbon) can be captured by **retaining the 'embedded' value** of products. The tighter the circle, the more that route should be prioritised to maximise retention of product value. Product reuse, and the selection and use of products with a long life, ought to be a high priority.

As an example, most surgical instruments are made in Pakistan, sometimes from stainless steel manufactured in Japan or Germany, and then shipped to healthcare facilities around the world. There is considerable embedded energy and carbon associated with the manufacture and distribution of those instruments, and reusing these retains the embedded value of that energy and carbon. Single-use devices that are remanufactured by a third party (represented by the refurbishment or remanufacturing loop, Figure 10), undergo transportation, repair, and loss, requiring additional resources and reducing the value compared to reusable instruments. Recycling is associated with the largest loop, as materials of products must be separated, and often undergo many steps to be made into new products. Currently, recycling markets are unreliable and contamination of recycling streams leads to much recyclable material being thrown away.[305] In the case of medical supplies, recycling could be called 'downcycling' as the recycled materials are of lower quality and functionality and so will almost never be able to be used to make medical supplies again. It can instead be used in other industries such as construction (e.g. steel for construction beams) and horticulture (e.g. PVC tree ties), and these usually cannot be further recycled at the end of their lifespan.

6.2 Manufacture and distribution

Provision of healthcare will always require manufacture and use of medical products and pharmaceuticals. There are frameworks which can be used at the product manufacturing stage to evaluate and encourage sustainability for medical devices, supplies, and pharmaceuticals. Surgical teams and procurement staff can challenge industry representatives to understand how a given product aligns with these sustainability frameworks, and to signal to manufacturers that this is what is expected of products used in healthcare.

The **Design for the Environment** or DfE framework (Box 2) emerged in the 1990s, providing guidance for product designers or research and development teams.[306] Applied to products of any sort, DfE prioritises environmental protection, human health and safety, and sustainability of resources. In essence, designers of medical products should think about all life cycle stages of their product: raw material extraction and sourcing, production and distribution, use and potential reuse, and end of life or disposal. They should estimate and track the environmental performance of their products and integrate learnings into new designs. Elements of DfE might include designing products with lower material diversity and interchangeable parts (modular) so that materials can be easily replaced or recovered (also known as 'design for revalorisation'). DfE might also encourage designers to 'design for detoxification'; that is, selecting materials that minimise the use of hazardous substances in either the product itself, the creation of the product, the use stage, or its final disposal.

Box 2: The 7 principles of Design for the Environment[306]

1. Embed life cycle thinking into the product development process
2. Evaluate resource efficiency and effectiveness of the overall system
3. Select appropriate metrics to represent product life cycle performance
4. Maintain and apply a portfolio of systematic design strategies
5. Use analysis methods to evaluate design performance and trade-offs
6. Provide software capabilities to facilitate the application of Design for the Environment practices
7. Seek inspiration from nature for the design of products and systems

Aligned with this, there are principles of Green Engineering,[307] which encourage designers to:

- Seek to ensure material and energy inputs are renewable and inherently non-hazardous
- Maximise efficiency of mass, energy, space, and time
- Reduce complexity and material diversity, making recycling and reuse easier
- Design products to meet (not exceed) needs
- Design products with the 'end of life' in mind
- Prevent waste wherever possible rather than handling once formed

Another widely popular framework is that of the Circular Economy (as discussed in section 6.1), which takes a life cycle view prioritising minimisation or elimination of produced waste. The principles of circular economy overlap with DfE, but they target whole companies or economies rather than single products or product lines. Aligning with these principles, some innovative companies are integrating recycled content into products and product packaging. Others have been developing compostable, bio-based plastics for medical supplies including Personal Protective Equipment (PPE) and disposable surgical products including receptacles, needle counters, and skin staplers.[308] However, a study evaluating the impact of substituting plastics within single-use hysterectomy devices with biopolymers found some environmental impacts (e.g. acidification, cumulative energy demand, carcinogenic effect) to be lower, and others (e.g. GHG emissions, eutrophication, ozone-depletion, smog-generation) to be higher.[309] Some studies outside of the healthcare context have associated bio-based plastics with lower carbon footprint, but the net environmental impact of using biopolymers is dependent on agricultural processes, waste systems enabling biodegradation, and potential recycling.[310]

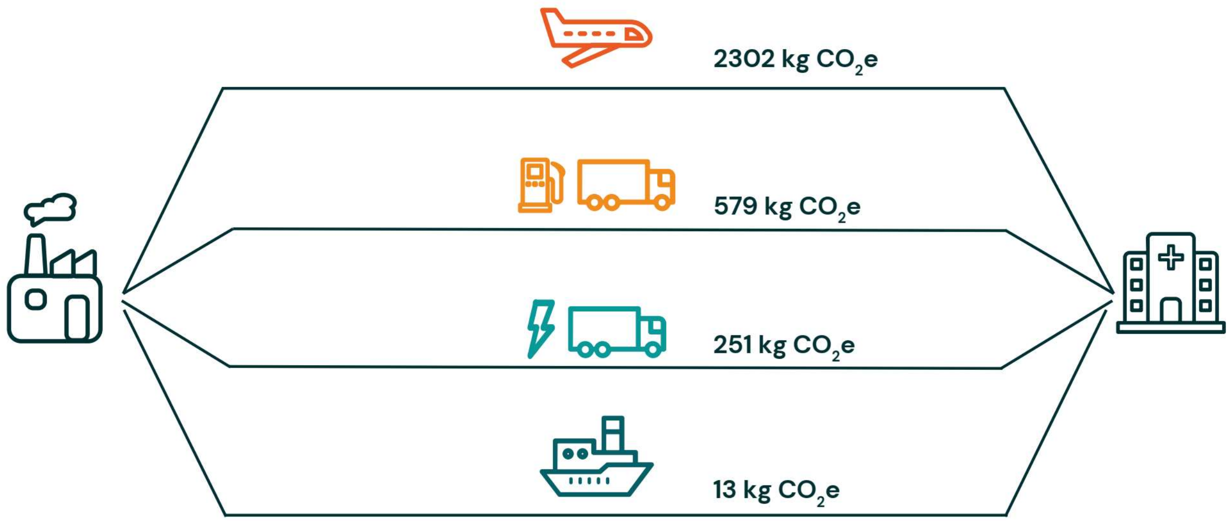
The predominant framework for improving sustainability of pharmaceuticals is called **Green Chemistry**,[311,312] which includes twelve principles ranging from waste reduction and energy efficiency, to less hazardous components and accident prevention.[313] Evidence on estimating and monitoring the environmental impact of pharmaceutical manufacturing and use are limited, as few methods exist, and we identify this as an area in need of development.

For the production and distribution of medical supplies, manufacturers need to apply DfE, Circular Economy, Green Engineering, Green Chemistry, and other environmental design principles to address sustainability. Manufacturers can also use standard life cycle thinking to minimise emissions associated with electricity use in factories and fuel use along distribution routes. For example, they can increase the proportion of **renewable energy sources** in manufacturing processes, through on-site renewable electricity generation (e.g. solar panels), supporting 'green' energy tariffs, or manufacturing in countries with higher proportions of renewables. There may also be opportunities to recover waste heat or to use natural cooling systems.

There are opportunities to reduce emissions associated with distribution processes through choice of mode of transportation (Figure 11), in particular **eliminating air freight** from healthcare supply chains. This may necessitate adequate planning and sufficient stocks to improve resilience, and avoid the need for urgent supplies. This can be further facilitated by expectations from healthcare providers, and a shift away from rapid (e.g. 48 hour) delivery requests.

Healthcare professionals can play a role in engaging with industry representatives about some of these factors (for example whether air freight is used within any stage of the product supply chain). Surgical teams may further ask suppliers whether they have sustainability plans to meet net zero targets, whether they publicly publish their emissions, or have set Science Based Targets.[314] Perhaps most importantly, they can ask why their product was not designed for reuse and longevity. The NHS roadmap for supplier alignment is considered in section 7.6.

Figure 11: Carbon footprint of alternative modes for transporting one tonne of medical products 1000km



Comparing transportation of 1 tonne of healthcare product 1,000 km, based on short-haul flight to and from UK, average diesel van, average battery electric van, average general cargo ship[315] We recognise there are wider environmental impacts beyond greenhouse gases, for example shipping contributes towards local ocean acidification through emissions of sulfur and nitrogen oxides in heavily trafficked routes.[316]

The wider context of the care pathways in which products are used should also be taken into account when considering sustainable product design, alongside logistical considerations associated with reuse, reprocessing and recovery of materials. For example, if there is robust evidence to support that use of a product over an alternative is associated with quicker operating time or reduced clinical complications, this should be included in analysis.

6.3 Opportunities to reduce and rationalise equipment

The largest reductions in environmental impact may be seen through reducing consumption of unnecessary items where this does not negatively impact on patient care.

Opportunities for making reductions (where clinically appropriate) include:

- Shifting the culture of opening items 'just in case', to '**open when required**', having items ready on standby, to be opened at the point of use
  - An evaluation of the cost of wasted single-use items (opened but not used) during endovascular neuro-interventional procedures found a mean average €679 per case[317]
- **Streamlining** single-use pre-prepared sets by liaising with industry to remove items not routinely used, and switching items in these sets to reusable alternatives where possible
  - One study found that 12 out of 40 single-use products in a pre-packaged tonsillectomy kit were unnecessary[318]
  - A study of hand operations found that an average of 11.5 products (out of 51 items) were disposed of without use, the majority of which were from a pre-prepared hand set,[319] whilst the development of a 'minimal' pre-prepared single-use set for hand surgery was associated with financial savings of US$125 per case[320]
- **Appropriate use of personal protective equipment**
  - For example, NHS standard infection control precautions indicate gloves should be worn when direct contact with blood and/or other body fluids, non-intact skin or mucous membranes is anticipated or likely.[321] However, habitual use of gloves for a wide range of tasks has become commonplace across healthcare settings including theatres, and is often inappropriate.[322,323] Not only does overuse of gloves increase the carbon footprint of care, but when they are put on too early and removed too late, they increase risk of microorganisms transmission between equipment and patients and vice versa.[324] Hand hygiene with either soap and water or alcohol hand gel is a more effective means of prevention cross-transmission and associated with lower CO_2 emissions (given that hand washing is required in addition to wearing gloves).
- **Eliminate unnecessary packaging** of surgical supplies and double wrapping where not indicated
  - For example, the Association of Surgical Technologists recommends double wrapping of individually wrapped 'supplementary' instruments only when packaging multiple or multi-component instruments,[325] yet this is sometimes seen for individual instruments, in part due to perceived convenience for theatre staff
  - There may be future opportunities for use of QR codes for accessing instructions for use, saving their inclusion in packaging
- Reduce volumes of paper using digital technologies (as per Section 3.1)

- Conventional scrubbing is associated with water wastage, with an estimated cost of around US$2,000 per year in an operating theatre in the USA.[326] At theatre design stage there may also be opportunities to reduce water consumption, for example through installing automatic or pedal controlled taps for surgical scrubbing, the latter estimated to save 5.7 L hot water, and 80 g CO_2e per surgical scrub.[327] The Intercollegiate Green Theatre Checklist[110] (Section 7) suggests use of alcohol gel in place of water and antiseptic scrub between cases.

CASE STUDY: Reducing unnecessary patient transfer sheets

Setting	Hywel Dda University Health Board
Patients	Endoscopy patients
Intervention	Elimination of slide sheet use for patient transfer where patient able to transfer self (estimated 90% of baseline use unnecessary)
Outcome	No impact on patient care
	↓ 3,726 kg CO_2e / year
	↓ £2,160 / year
	Improves patient independence

Source: Centre for Sustainable Healthcare[328]

6.4 Reusable equipment

There has been a disturbing trend toward single-use disposable medical devices over the past three decades that is rapidly accelerating. Simple devices such as blood pressure cuffs,[329] pulse oximetry probes, and laryngoscopes,[330] as well as complex devices such as laparoscopic instruments,[331] duodenoscopes,[332] and bronchoscopes[333] may now be single-use. In addition to ecosystem destruction from natural resource extraction, fossil fuel combustion to provide energy for manufacturing, and waste disposal management also harms human health. Whilst reuse is not appropriate for items difficult-to-decontaminate with current technologies (such as needles and intravenous tubing), reviews in surgical contexts[45] and across healthcare[193,302] associate reusable equipment with lower environmental impact relative to single-use equivalents in almost all cases (Table 6), with average **reductions in carbon footprint of 38-56% through switching from single-use to reusable products**.[193]

Whilst reductions in GHG emissions have been demonstrated for reusable products across a range of categories (Table 6), shifting towards reusable textiles may have particular potential for impact as these are common to most surgical procedures and associated with high carbon burden. For example, single-use personal protective equipment, and patient and table drapes were responsible for mean 25% of carbon footprint of products used in five common operations.[297] Previous review of **surgical gowns and drapes** found **reductions in carbon footprint (200-300%), water footprint (25-330%), and waste generation (750%)**.[334] A review by the WHO Global Guidelines for Prevention of Surgical Site Infection found no evidence of difference in surgical site infection rates when single-use versus reusable drapes were utilised.[335] In fact, there are potential benefits (beyond environmental) associated with reusable linens including higher water resistance, strength, and pilling resistance (demonstrated for gowns).[336]

Table 6: Evidence for lower carbon footprint associated with reusable products compared with single-use equivalent

Product group	Product	Carbon footprint per case of reusable (X%) relative to single-use	Source
Airway devices	Laryngoscope blade Laryngoscope handle	14-50% 4-14%	Sherman et al. (2018)[330]
	Laryngeal mask airway	65%	Eckelman et al. (2012)[337]
Surgical instruments	Dental burr	35%	Unger et al. (2014)[338]
	Laparoscopic clip applier**	17%	Rizan et al.(2022)[339]
	Laparoscopic trocar**	18% 27%	Boberg et al.(2022)[340] Rizan et al.(2022)[339]
	Laparoscopic scissor**	33%	Rizan et al.(2022)[339]
	Surgical scissor	3%*	Ibbotson et al. (2013)[341]
	Vaginal speculum	33-37% 17%	Donahue et al. (2020)[342] Morris and Hicks (2022)[343]
Surgical scopes	Cystoscope	22%	Kemble et al.(2023)[344]
	Duodenoscope	2-4%	Le et al.(2022)[345]
Surgical products	Anaesthetic drug tray	87%	McGain et al. (2010)[346]
	Blood pressure cuff	7-8%	Sanchez et al (2020)[347]
	Laparotomy pad	54%	Kummerer (1996)[348]
Textiles	Surgical face mask	58%	Lee et al. (2021)[349]
	Surgical gown (and huck towel)	34% 51%	Vozzola et al. (2020)[350] Carre et al. (2008)[351]
Waste products	Suction receptacle	3%*	Ison et al (2000)[352]
	Sharps container	17% 35% 16%	Grimmond et al. (2012)[353] McPherson et al. (2019)[354] Grimmond et al. (2020)[353]

=estimated from chart,= hybrid (predominantly reusable, small single-use component)*

There are a small number of studies which suggest that the carbon footprint of single-use products is lower than reusable equivalents (Appendix 3). The majority of these studies were undertaken in Australia,[355-357] or have assumed Australian electricity supply.[358] Australia has a high proportion of non-renewable energy sources and has been slow to decarbonise its energy supply. These results do not apply where surgical products are used and reprocessed using electricity with higher proportion of renewable (versus non-renewable) energy sources, such as Europe or the USA. Other studies that apparently favour single-use products lack transparency,[359] compare inequivalent products (the same 'functional unit' should be compared in such studies),[360] or have methodological flaws.[358]

Reliable analysis of the carbon footprint of endoscopes are an important gap in knowledge. One study found single-use duodenoscopes generated up to 47 times the carbon footprint of reusable duodenoscopes (with production accounting for up to 96% of the carbon footprint),[345] whereas a study of cystoscopes suggested single-use was better[358] but was subsequently shown to have methodological flaws.[361]

CASE STUDY: Switching to reusable named surgical caps

Setting	Liverpool University Hospitals NHS Trust
Intervention	Reusable named fabric surgical caps
Outcome	Better communication between staff members
	↓ carbon footprint– see systematic review above
	↓ £53,202 / 3 years
	↓ patient anxiety Staff reported feeling more valued being addressed by name

Source: Centre for Sustainable Healthcare[162]

In summary, in almost all cases reusable products are associated with lower carbon footprint compared with single-use items.[45,193,302] The switch to reusable alternatives should be particularly encouraged in settings where single-use equipment is commonly used, including emergency departments, outpatient and primary care settings, and operating theatres. Some of the potential barriers to switching to reusables such as infection prevention policy and practice, and supporting infrastructure are considered in sections 7.4 and 7.6.

There are often **cost savings associated with switching to reusables** where full life cycle costs are taken into account. For example, switching from single-use to reusable laryngoscope blades and handles was associated with savings of up to US$604,000 and US$265,000 respectively per year at a single hospital.[330] Switching from single-use to reusable anaesthetic equipment was associated with an estimated £19,220 per year saving (46% decrease) in an Australian hospital.[355] Switching from single-use to hybrid (predominantly reusable) laparoscopic scissors, ports, and clip appliers was modelled to save over £11 million if adopted for all laparoscopic cholecystectomies in England.[339] There are also initiatives to increase reuse of equipment in the wider surgical patient pathway. For example, reusing walking aids (such as crutches, frames and walking aids) is estimated to save the average hospital £46,000 per year (assuming just one in every five is returned).[363]

CASE STUDY:
Switching to reusable ports and instruments for laparoscopic appendectomy

Setting	University Hospitals Plymouth NHS Trust
Patients	Patients undergoing laparoscopic appendectomy
Intervention	Replacing single-use ports and instruments (Johann graspers, scissors, Maryland forceps) with reusable equivalents
Outcome	↓ 0.5 tonnes CO_2e / year
	↓ £34,400/ year
	>90% staff responding to survey would now consider sustainability within their practice

Source: Centre for Sustainable Healthcare[162]

6.5 Reprocessing

In between uses, reusable products must be reprocessed. This involves cleaning, followed by microbial inactivation through disinfection and/or sterilisation, thereby enabling safe reuse.[365] Microbial inactivation for reusable instruments is most often achieved using steam (recommended as preferred method of sterilisation by WHO),[366] although alternative low-temperature methods include ethylene oxide, vaporised hydrogen peroxide gas plasma, formaldehyde gas, or ozone.[365,366] Different sterilisation methods will be appropriate for different surgical products, for example ethylene oxide is suitable for devices that would otherwise be damaged by moisture and/or heat, and also suitable for devices with lumens,[366] such as endoscopes.

Whilst significant carbon footprint reductions (average 38-56%)[193] are seen through switching from single-use to reusable products, once a reusable item is in place the majority of the carbon footprint typically relates to this reprocessing phase; as illustrated in studies evaluating laryngoscope blades and handles (reprocessing responsible for almost all greenhouse gas emissions),[330] and surgical scissors (85%).[341] Sterilisation of reusable products was also found to be responsible for 20% of the carbon footprint of all products (including both single-use and reusable) used for the five most common operations in England.[297]

Strategies that can be used to optimise the carbon footprint of sterilisation processes include:

- Reprocessing **instruments as sets containing multiple instruments** (rather than supplementary, individually wrapped items)
    - The carbon and financial cost of processing an instrument as part of a set (66-77g CO_2e, £0.90-0.92 per instrument undergoing steam sterilisation) is lower than individually wrapped instruments (189 g CO_2e, £6.34 per instrument)[367]
    - Individually wrapped items are usually prepared in single-use flexible peel pouches, associated with inefficient loading of decontamination machines

- Conduct decontamination machine test-runs loaded with sets
    - Decontamination machine test-runs (to verify sterility assurance standards) can be conducted loaded with instruments, which can then be put into circulation for clinical use (provided the test passed, as is the norm)
- **Maximise loading** of decontamination machines (washer-disinfector and steriliser)[367]
    - This can be facilitated through adequate stocks of reusable equipment to ensure clinical requirements for instruments can be met, and may be easier where sterilisation facilities are centralised
- **Minimise** decontamination machine **standby time**
    - In one study standby time was found to be responsible for 40% of a steam steriliser's daily total energy and 20% of its water consumption[368]
    - Switching off decontamination machines idle for two or more hours (estimated to be 42% of the time in an Australian study) can save a quarter of electricity use and 13% of water consumption of steam sterilisers[369]
- Increase proportion of **renewable** energy supplies
    - Achieved through local on-site renewable energy generation, or encouraged through green energy tariffs

Surgical teams may liaise with on and off-site sterile services to encourage adoption.

Different sterile barrier systems (used to house surgical instruments) will also have different carbon footprints, with highest impacts associated with single-use flexible peel pouches for individually wrapped instruments.[367] The carbon footprint of reusable rigid containers has been found to be higher (721 g CO_2e per set), than single-use tray wraps (387 g CO_2e per set) principally due to the additional washing required for the rigid containers (which is inefficient due to their bulkiness).[367] This contrasts with findings from a different study[367] which found that the carbon footprint of reusable rigid containers was 85% less than that of single-use tray wraps,[370] with significantly lower estimate for reusable rigid containers (57 g CO_2e per use); however, the underlying assumptions about energy consumption in the latter study need reconsideration.[370] Regardless of the choice of sterile barrier systems, the most important take-home message is to use reusable instruments where possible, to prepare these as sets, and to only remove items from the set that are never or very rarely used. There are opportunities also to **recycle sterile barrier systems**, modelled to reduce the carbon footprint of single-use tray wrap by 6%, and 3% for reusable rigid containers.[367]

Reusable linens need to be laundered (enabling cleaning and disinfection), and sterile linens (such as surgical gowns and drapes) undergo steam sterilisation in a similar manner to surgical instruments. Opportunities to optimise the environmental impact of healthcare linen laundering has received little attention. However, the principle of optimising machine loading and utilising renewable energy sources can also be applied here, alongside use of **environmentally preferable detergents**,[371] and **capture of microfibres** which may be released during washing.[372]

CASE STUDY: Switching to reusable linens and optimising reprocessing		
Setting	Royal Cornwall Hospitals NHS Trust	
Patients	Specialist Orthopaedic and Breast Surgery hospital, with four operating theatres	
Interventions	• Switch from single-use surgical gowns and operating theatre drapes to reusable equivalents • Installation of modular medical textiles reprocessing unit on site • Developing and validating low temperature decontamination processes	
Outcome	↓ 67 tonnes CO_2e / year (assuming 75% capacity THR equivalents for 4 theatres working 5 days a week for 52 weeks)	
	↓ £10,000/ year	

Source: Direct Submission from Tom Dawson

6.6 Extend lifespan of products: repair and remanufacture

There are opportunities to extend the lifespan (number of uses) of a given product through repair of reusable items and remanufacture of single-use products. When a reusable surgical item becomes damaged, or no longer functions optimally, there may be options for **repair rather than replacement**. Repair forms part of the 'circling longer' principle, that reduces the need for acquisition of virgin materials, consumption of energy, and use of labour.[373]

Analysis of >14,000 repairs over 11 years at Barts Health NHS Trust reported that of instruments successfully repaired, over half were general surgical scissors such as Mayo, Metzenbaum or McIndoe scissors (52%), followed by osteotomes (6%), needle holders (6%), retractors (4%), and clamps (4%).[374] Surgical scissors repair was associated with **carbon savings of 20%**, and cost savings of one-third, compared with purchase of a new pair of scissors (Figure 12).[374] However, offsite repair can sometimes cause delays, and so good communication between parties is needed to optimise services, and in some cases may also require hospitals having spare stock.[374]

Figure 12: Repair of surgical scissors

Where 'single-use' products are in use, it is possible to gain one or more additional uses through remanufacture, whereby products are evaluated, parts are repaired or replaced as necessary, and products are re-certified. Carbon reductions have been demonstrated for remanufacture compared to single-use products, including for electrophysiology catheters (half the carbon footprint)[375,376] and a range of other products (arthroscopic shaver, deep vein thrombosis compression device, endoscopic trocar, ligasure, pulse oximeter, scissor tip, and ultrasonic scalpel).[377] This has also been associated with cost savings, for example reprocessing of a deep vein thrombosis compression sleeve once was estimated to save around US$75,000 at a US hospital per year, whilst reprocessing it five times (getting total of six uses out of the device) was associated with cost savings of over US$123,000.[377]

However, the reductions associated with switching from single-use to reusable products are usually greater than switching from single-use products to remanufactured products. We also caution that the environmental impact of using remanufactured products will depend upon the transportation distances and modes of travel (for example reductions may be offset if air freight is used), alongside the proportion of products which can be successfully remanufactured, which is product dependent.

6.7 Waste and recycling

When seeking to improve sustainability, waste disposal and recycling are prioritised and considered to be important sources of emissions. However, waste plus water are together responsible for only 5% of NHS England's carbon footprint,[22] and analysis focusing exclusively on the products used in five common operations found waste disposal was responsible for 9% of the carbon footprint.[297] In contrast, seeking to reduce volumes of waste has a larger potential (beyond the environmental impact of processing of waste), indicating reduced embodied carbon upstream in the supply chain (including manufacture and distribution of single-use products). Auditing the generation of waste in a surgical department can be used as a **proxy for volumes of single-use items consumed**, but should primarily be used to identify opportunities for upstream reduction.[378]

Nevertheless, optimising healthcare **waste disposal** does present an opportunity to further reduce the carbon footprint. Hospitals can seek contracts with companies that **recover energy from waste** (whereby energy is generated, bottom ash and slag metals are recovered and reused), which is feasible for both high and low temperature incineration (42%[379] and 50%[380] reductions in carbon footprint respectively). Infectious waste is defined as waste contaminated by a known pathogen, not just contaminated with blood and/or body fluid. Infectious waste (orange bags) must undergo decontamination prior to waste disposal (for example via autoclave, dry heat, micro-/macrowaves, steam auger, or chemical disinfection),[381] with additional environmental impacts (338kg CO_2e/tonne waste autoclaved).[380] An audit of anaesthetic waste found 16% of waste disposed in infectious waste streams was not contaminated, whilst 7% of waste disposed of in general waste streams was infectious.[382] This highlights the importance of accurately segregating waste to ensure the carbon footprint associated with its disposal is as low as possible.

The environmental impact of using landfill (relative to the impact of sending items for incineration) is dependent upon the waste materials (and their biogenic and fossil fuel-derived carbon content). For instance, disposing one tonne of metal or plastic via landfill is associated with 9 kg CO_2e, one tonne of linens with 445 kg CO_2e, paper with 1,042 kg CO_2e, and food and drink with

627 kg CO_2e.[315] However, there are factors beyond GHG emissions that affect the environmental impact of waste streams, for example landfill has a lower impact on human toxicity and photochemical oxidation but higher impact on terrestrial ecotoxicity than incineration.[379,383]

Table 7: Disposal of healthcare waste

Waste stream		Waste receptacle	Description
Non-hazardous waste	Dry mixed recyclable waste	Clear bag	This will depend on local recycling facilities, but may include sterile packaging, paper, cardboard, plastic bottles
	Domestic waste	Black bag	This is the equivalent to municipal household waste, for example hand towels
	Non-infectious offensive waste	Yellow/black striped bag	This should be used for item which 'may cause offence' e.g. contaminated with body fluids, odour
	Infectious waste	Orange bag	This should be reserved for items in contact with a patient known (or suspected) to have a disease caused by a microorganism or associated toxins (where hazardous waste criteria not fulfilled)
Hazardous waste	Clinical waste	Yellow bag	Infectious waste contaminated with chemicals or pharmaceuticals
	Medical contaminated sharps waste	Yellow lidded yellow box	Sharp products contaminated with medications
	Anatomical waste	Red lidded yellow container	Body parts, including anatomical waste such as amputated tissue, diagnostic specimen, blood bags
	Medicinal waste	Blue lidded yellow box	Unused (or part used) medicines

Waste types based upon UK Department of Health guidelines.[381] Note hazardous waste contains infectious pathogens, cytotoxic medicines, or medicines/ chemicals that harm humans or the environment including those with radioactive properties.

It is important that healthcare staff have access to appropriate waste disposal routes, alongside education on how to sort waste appropriately (Table 7). For example, **infectious waste bags should be used only when there is clear risk of infection** because inappropriate use causes unnecessary carbon and financial burden. **Segregation** of waste could be improved through clearer waste terminology. For example, the stream for infectious waste contaminated with chemicals is commonly confusingly labelled 'clinical waste', which leads people to utilise this route for disposal of waste from an operating theatre that is not infected.[381] Appropriate waste segregation is also associated with financial savings,[380] for example a series of initiatives to improve use of medical waste streams in a USA tertiary hospital was associated with financial savings of around US$288,012 per year.[384]

Recycling

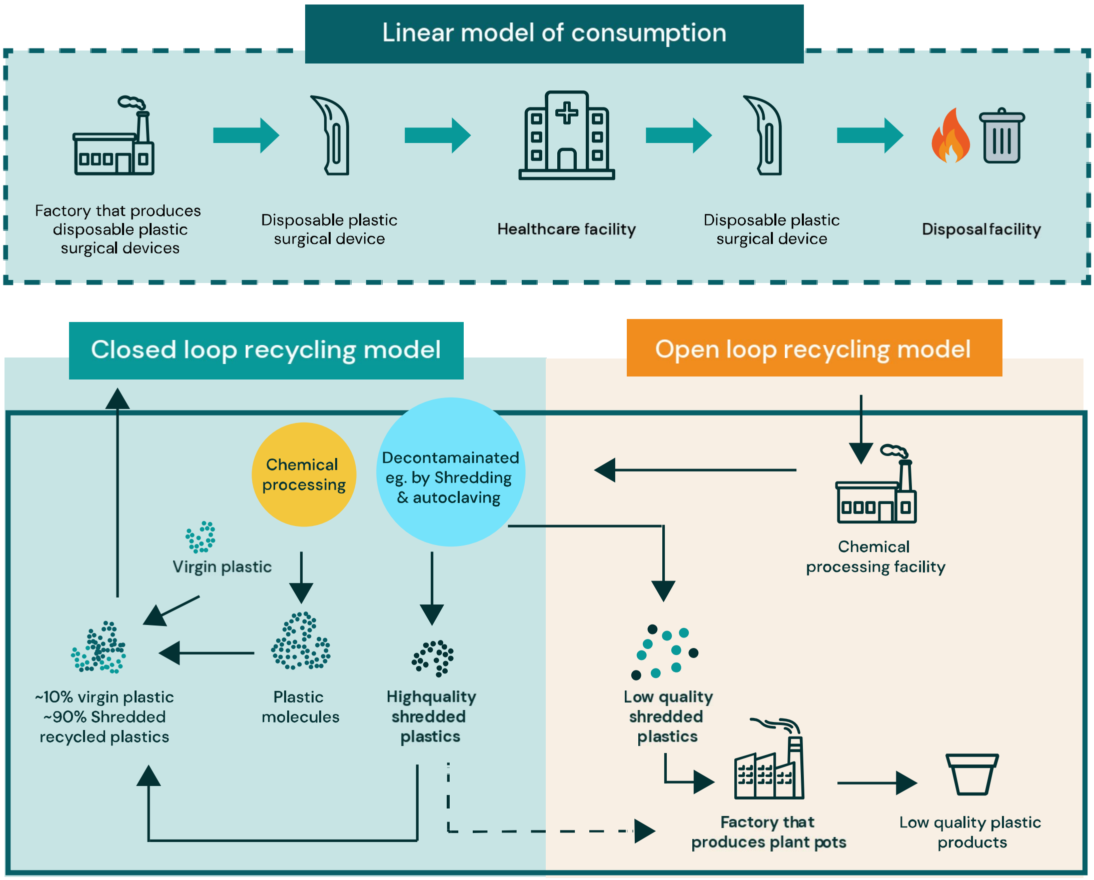
In line with circular economy principles, waste minimisation ought to be pursued, alongside efforts to recover and reuse materials, keeping them in use at their highest function for as long as possible. Where items are recycled, emissions associated with the transportation from hospital to recycling facility, and recycling process, are assigned to the products for which the recycled materials are integrated. Similarly the benefit of not needing to acquire new virgin materials is also assigned to the new product.[385] For example, where stainless steel instruments are recycled into materials for construction, the offsets due to reduced need for virgin metal extraction are assigned to that construction. This means that for the healthcare sector to be assigned benefit from recycling, we need to **increase the proportion of recycled content** (amount of recycled materials) used within healthcare products themselves.

The proportion of operating theatre waste that is potentially recyclable has previously been estimated at 55% by weight.[386] This can be increased if infectious waste is decontaminated before recycling. For example, there are services which decontaminate surgical instruments prior to using that steel in the construction industry, and there is potential to expand this to other healthcare waste materials. There can be financial savings associated with recycling. In a hospital in the USA, the sale of recycled blue instrument tray wrap was estimated to generate US$5,000 per year and a further annual saving of US$174,240 from avoided waste disposal.[387] There is large variation in recycling rates between UK hospital sites. For example, an evaluation of Mohs micrographic surgery at twelve sites across the UK found the recycling rate ranged 0-44%.[388]

The ability of a product to be recycled depends on several factors, one of which is the circularity potential, meaning the potential ability of recycled elements to be reused and meet the high-quality standards necessitated by the healthcare industry.[389] There are many challenges associated with plastic recycling.

To improve their circularity potential, healthcare products should be created in ways that allow for easy disassembly into component parts for recycling, and which minimise the mixing of different plastics in waste. If the plastics can be sorted, they can be used for products of different material quality. When recycled plastic is used to create a lower quality product, such as a plant pot, this is known as downcycling. The process of downcycling falls into a category known as open loop recycling, which refers to a recycling process where the recycled material is used for a different market application than that of the previous life cycle.[390] However the ideal recycling process is one called a **closed loop recycling process**, whereby the quality of the material is kept high during recycling, and so the recycled material could be reused for the same market application as that of its previous life cycle (Figure 13). For example this could be achieved through novel processes such as autoclaving and shredding,[391] to create shredded safe plastics feedstock to create similar healthcare products. Another process within the closed loop model is chemical recycling whereby plastics are broken down and depolymerised, and can subsequently be used to produce fuels, or virgin plastics.[390]

Figure 13: Open versus closed loop models of recycling



CASE STUDY: Recycling surgical wrap

Setting	Cork University Maternity Hospital, Gynaecological theatre	
Intervention	Recycling of single-use polypropylene surgical wrap used for gynaecological surgeries	
Outcome	No impact on clinical care	
	↓ 2.2 tonnes CO_2 / year	
	Cost €733/ year	

A team at the Cork University Maternity Hospital (CUMH), in Wilton, Cork, Ireland, prospectively quantified the polypropylene surgical wrap generated by a single gynaecology theatre in the hospital, with a view to recycling. In 2019, 1,909 gynaecological surgeries were performed at CUMH.

The group found that surgical wrap comprised 11% of operating theatre waste. A total of 66 surgeries were performed over a five-week period in 2022, from which 221 individual sheets of surgical wrap were collected, equating to 282m^2 of polypropylene wrap. The team estimated 711 kg of surgical wrap could be recycled annually from their gynaecology theatre, equating to 2.2 tonnes of CO_2e. It was estimated that disposal of the wrap in the general waste stream would cost €107 per annum, but only €35 per annum in the recycling stream (although due to contractual obligations these cost savings were not realised at CUMH).

Source: Direct submission David James Rooney

Section recommendations

Recommendation	Short term	Long term	Stakeholders
R6.1 Ensure that design and manufacture of products minimise the environmental impact throughout the product lifespan	Opt for renewable energy sources[a] Ask suppliers if they have a carbon reduction plan[b,c]	Apply principles such as Circular Economy, Design for the Environment framework, principles of Green Engineering, or Green Chemistry principles[a] Develop a carbon reduction plan (if not already in place)[a]	Industry[a] Procurement teams[b] Surgical and anaesthetic teams[c]
R6.2 Ensure that modes of distribution with lowest environmental impact are chosen	Ask industry representatives whether air freight is used at any stage of product supply chain[b,c]	Shift culture away from urgent delivery requests (reducing reliance on air freight) through adequate planning, sufficient stocks[b,c] Seek to eliminate air freight from distribution, electrify vehicular fleet[a]	Industry[a] Procurement teams[b] Surgical and anaesthetic teams[c]
R6.3 Reduce and rationalise equipment	Only open items when required[c] Rationalise unnecessary equipment and investigations (e.g. avoid gloves where hand washing appropriate)[c]	Streamline single-use pre-prepared sets[a,b,c] Eliminate unnecessary packaging[a]	Surgical and anaesthetic teams[c] Procurement teams[b] Industry[a]

R6.4 Switch from single-use to reusable equivalents where available	Opt for reusable equivalents where currently stocked are available[c]	Explore whether reusable alternative currently available on the market and trial/purchase[c,b] Model increase in demand for reprocessing of reusable equipment, plan to increase capacity accordingly[b,d,e] Design products for safe reuse[a]	Surgical and anaesthetic teams[c] Procurement teams[b] Instrument and textile reprocessing services[d] NHS and healthcare provider management teams[e] Industry[a]
R6.5 Optimise reprocessing of reusable equipment	Switch off idle machines[d] Run decontamination machine test-runs loaded with sets[d]	Prepare instruments as sets[d] Use renewable energy sources, environmentally preferable detergents[d] Maximise loading of decontamination machines, whilst minimise standby time[d]	Instrument and textile reprocessing providers[d]
R6.6 Extend the lifespan of reusable products through repair and remanufacturing	When an item is damaged find out if it can be repaired[c,d]	Explore opportunities for repair and remanufacturing (where such contracts not in place)[f,d,g] Design products that are modular, facilitating repair[a]	Surgical and anaesthetic teams[c] Theatre managers[f] Instrument and textile reprocessing services[d] Repair services providers[g] Industry[a]

R6.7 Optimise waste	Use appropriate waste streams[c]	Education on appropriate use of healthcare waste streams[h] Opt for contracts with waste handling companies which enable recycling and recovery of energy from waste where possible[i] Facilitate appropriate waste segregation[i] Design products to facilitate recycling (e.g. made of as few different materials as possible)[a] Design products using maximal recycled content[a]	Surgical and anaesthetic teams[c] Educators[h] Facilities and estates[i] Industry[a]