# 1. Introduction

## Section key points

- Climate change is the greatest threat to human health in the 21st century.
- Healthcare provision contributes to ~4.4% of total global greenhouse gas emissions.
- Surgical care is a major area of resource consumption, with the carbon footprint of surgical care in the UK in 2019 estimated at 5.7 million tonnes $CO_2e$.
- Carbon hotspots in the operating theatre include anaesthetic gases, energy, and products (particularly single-use).
- There are known labour rights abuses within the supply chain of products used in surgical care.
- Sustainable surgery involves providing high-quality, high-value surgical care in a way that is environmentally, socially, and financially sustainable.
- The NHS, alongside the healthcare systems of 27 other countries have committed to Net Zero Carbon targets; the majority of UK healthcare staff and the public support this ambition.

## 1.1 Interplay between human health and planetary health

Following the industrial revolution of the late eighteenth century, a new geological era began (the 'Anthropocene'), in which human activities became the primary driver of environmental change.[2] **Planetary boundaries** describe environmental thresholds within which humanity can safely survive and thrive, of which four have already been crossed; climate change, land-system change, loss of biosphere integrity, and altered biogeochemical cycles (others considered in the 'safe' zone are stratospheric ozone depletion, ocean acidification, and freshwater use, whilst atmospheric aerosol loading and novel entities have not yet been quantified).[3] An additional planetary boundary relating to 'green water' has recently been defined (relating to terrestrial precipitation, evaporation, and soil moisture), and has already been crossed.[4] **Climate change** can be defined as long-term changes in mean average weather conditions, or their increased variability,[5] and is considered a 'core' planetary boundary due to its importance to stability of other environmental systems.[3]

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that **human activity is the unequivocal cause of rapid global warming of the atmosphere, land, and oceans**.[6] This is driven largely by anthropogenic (originating in human activity) emissions of gases which absorb infrared radiation (greenhouse gases, GHGs), including carbon dioxide ($CO_2$), methane, nitrous oxide, and halogenated gases.[6] The rate of climate change is unprecedented and accelerating, with atmospheric $CO_2$ (forecast global average 419.2 parts per million in 2023) at its highest ever concentration in two million years.[7]

The landmark Paris Agreement set a legally binding international treaty to limit global warming to 2 °C, preferably 1.5 °C (compared with pre-industrial levels). It was signed by 196 parties at the 21st United Nations (UN) Climate Change Conference (COP21) in 2015.[8] The majority of countries (representing 90% of world Gross Domestic Product) have committed to reaching **net zero emissions** by the middle of this century,[9] defined as the state in which anthropogenic GHG emissions are balanced by anthropogenic removal of such emissions.[5]

### Box 1: A note on Carbon Footprints and Life Cycle Assessment (LCA)

Around three-quarters of anthropogenic GHG emissions are made up of carbon dioxide,[10] and $CO_2$ is therefore used as a reference gas. Non-$CO_2$ GHGs can be assigned a global warming potential (GWP), based on the amount of radiative forcing (heating effect) associated with one tonne of a given gas relative to one tonne of $CO_2$, over a set time-period,[5] typically 100 years. In this report, a '**carbon footprint**' is defined as the estimation and summation of direct and indirect GHG emissions associated with a given product or process, including non-carbon GHGs which are converted to carbon dioxide equivalents ($CO_2e$) based on their global warming potential.

The term 'carbon' is sometimes used as shorthand to encompass other GHGs; for example, 'net zero carbon', 'carbon cost', or 'reduce carbon' may relate specifically to $CO_2$, but often implies inclusion of other GHGs (as in this report).

In this report, a **life cycle assessment** (LCA) is defined as the evaluation of the cumulative environmental impact of a product or process across a range of environmental impact categories, including but going beyond only the carbon footprint. Through applying a consistent methodology to different units of analysis (e.g. different products serving the same clinical function), this allows us to quantify and compare environmental impacts.

## Impact of climate change on human health

Planetary health is intricately linked with human health, and climate change has been proposed as the greatest threat to human health in the 21st century.[11] Climate change threatens public health through:

### Direct impact of extreme weather events

- For example, heatwaves, flooding, drought and storms.[12]
- Modelling indicates global warming of 4.1 °C could lead to 83 million cumulative excess global deaths between the year 2020 and 2100, whilst limiting warming to 2.4 °C could avert nearly 90% (74 million) of those deaths.[13] This model assumes a mortality cost of carbon at one excess death per 4,434 metric tons of $CO_2$.[13]

### Indirect impacts of global warming

- For example, those associated with poor air quality, food and water insecurity, and transmission of climate-sensitive infectious disease.[14]
- Air pollution is the largest environmental cause of morbidity and premature death, with 3.3 million deaths attributable to anthropogenic air pollution in 2019.[12] We note that whilst a small proportion of air pollution relates to climate change itself (such as temperature inversions, desert dust movement),[15] the majority of air pollution is caused by the extraction and burning of fossil fuels (which also drives climate change).[16]

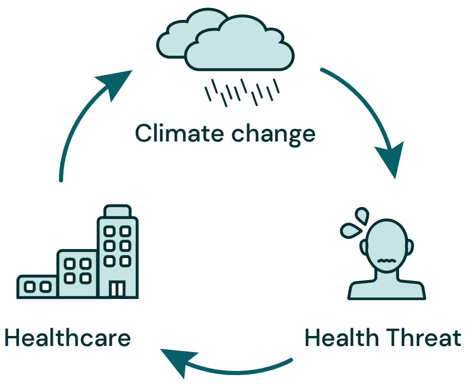
Vulnerable individuals are at greatest risk of climate-related health impacts including those with existing health conditions, older people, and children.[12] Health impacts of climate change also risk **widening inequalities** (and the associated health gap) and follow a social gradient, with those at highest levels of socioeconomic deprivation most likely to suffer from food and water insecurity, whilst also being least able to adapt their homes or move, and to suffer disproportionately from uninsured losses.[14] In contrast, the poorest half of the world population contributes only a small fraction of global GHGs (estimated at 7%), demonstrating **climate injustice**.[17]

Health and equity were more prominent topics in the 2021 UN Climate Change Conference of Parties (COP26) than in previous COP meetings. This led to more than 70 countries committing to strengthen the climate resilience and lower the emissions of their health systems.[18] The World Health Organization (WHO) released a special report ahead of the conference, calling upon government and policy makers to rapidly bring about transformative change to protect both planetary and human health.[14] An open letter entitled 'Healthy Climate Prescription' signed by 600 organisations representing 46 million nurses, doctors and healthcare professionals globally called upon world leaders to **"avert the impending health catastrophe by limiting global warming to 1.5°C, and to make human health and equity central to all climate change mitigation and adaptation actions"**.[19] An editorial published in over 220 health journals delivered a similar message.[20]

## Environmental impact of healthcare

Whilst climate change threatens human health,[11] healthcare provision paradoxically contributes to the problem (Figure 1).

**Figure 1: Interplay between human and planetary health**




Health Care without Harm estimated that the **healthcare sector is responsible for 4.4% of global net emissions**, and that if the healthcare sector were a country it would be the fifth largest emitter.[21] The National Health Service (NHS) in England generates an estimated 25 million tonnes $CO_2e$ per year,[22] responsible for around 4% of national GHG emissions.[23] This includes three 'scopes' of greenhouse gas emissions (Table 1).

**Table 1: NHS England Greenhouse Gas (GHG) contributions[22]**

| Scope | Definition | Example | Responsible for % of NHS England GHG emissions |
|---|---|---|---|
| **Scope 1** | GHGs directly emitted from (and controlled by) an organisation | • Anaesthetic gases<br>• Hydrofluorocarbons or chlorofluorocarbon propellants from metered dose inhalers | 5% |
| | | • Direct emissions from combustion of petrol or diesel from NHS owned and leased vehicles | 4% (alongside other business travel– categorised as scope three emissions) |
| | | • Combustion of fossil fuels onsite (such as within gas boilers) | 10% |
| **Scope 2** | GHGs indirectly emitted due to energy purchased | • Purchased energy in the form of electricity, steam, heating or cooling | |
| **Scope 3** | All other GHGs | • Supply chain, including:<br>• Pharamaceuticals and chemicals<br>• Medical equipment<br>• Non-medical equipment | 62% |
| | | • Patient, visitor and staff travel | 10% |
| | | • Water and waste disposal | 5% |
| | | • Commissioned services | 4% |

GHG emissions associated with the supply chain for healthcare made the largest contribution to the NHS carbon footprint (almost two-thirds), of which pharmaceuticals and chemicals (20% of total) and medical equipment (10% of total) were the biggest contributors.[22] 'Medical equipment' includes products used directly for delivery of healthcare such as surgical instruments, syringes for administering medications, and medical gloves.

The environmental impact of healthcare delivery extends beyond global warming, for example nitrous oxide and halogenated anaesthetic gases such as isoflurane contribute to **ozone depletion**, reducing the shielding effect of the atmosphere from ultraviolet radiation and increasing risk of skin cancer in affected regions.[24] The healthcare sector contributes to **air pollution**, and has been estimated to generate 2.8% of global particulate matter ($PM_{10}$) emissions, and 3.4%-3.6% of the air pollutants nitrogen oxides and sulphur dioxide.[25] In England in 2017 it was estimated that 3.5% of all road travel was related to the NHS (9.5 billion road miles), and generated 330 t of $PM_{2.5}$ and 7,285 t of nitrogen oxide.[26] The provision of healthcare also has a large **water footprint** (estimated at 2.23 billion $m^3$ in England),[26] contributing to water scarcity.[25]

**Ecotoxicity** refers to adverse effects of anthropogenic chemical, physical, or biological agents on ecosystems. Use and disposal of pharmaceuticals is associated with increased concentrations of bioactive pharmaceutical compounds in water systems and soil, including antibiotics, analgesics and anti-inflammatory drugs.[27] Pharmaceutical residues may be absorbed by other species such as fish, reptiles, and birds, at a rate faster than elimination, leading to bioaccumulation.[27] Healthcare is increasingly reliant upon **single-use plastics**, with the global medical plastics market responsible for 2% of total plastics production by value, and growing by 6.1% per year.[28] This contributes to global warming through burning of fossil fuels in manufacturing processes,[29] and contributes to accumulation of plastic fragments in our biosphere. There is also evidence of high levels of **microplastics** in the operating theatre, which may be due to the high levels of plastic materials in use.[30] The consequences of such exposure to the health of staff or patients are not yet fully known, and there is emerging evidence that some microplastics and their additives can induce cytotoxicity, hypersensitivity, immunotoxicity, and endocrine disruption.[31]

In light of increased awareness of both the impact of planetary health on human health and the environmental impact of the healthcare sector itself, there is a growing movement towards mitigating the environmental impact of healthcare provision. The United Kingdom (UK) has been a leading proponent of sustainable healthcare. The Well-being of Future Generations Act was passed in Wales in 2015, requiring public bodies to consider the UN Sustainable Development Goals and climate change.[32] In 2019, Scotland became the **first national healthcare system to commit to meeting net zero carbon emissions** (as part of wider Scottish Government targets).[33] **The Greener NHS in England** (formed in 2020) was the first national healthcare organisation to publish a full strategy to decarbonise the healthcare system, setting targets for meeting net zero carbon emissions within the direct control of the NHS by 2040, and to extend this to those in the supply chain by 2045.[23] All these policies were built upon the foundation of the NHS Sustainable Development Unit Carbon Reduction Plan, first formulated in 2009.[34] **The UK became the first country to integrate this into legislation**, amending the Health and Care Act in 2022 to specify compliance with the Climate Change Act, and the Environment Act.[35]

27 countries have now joined the UK in making Net Zero commitments for their healthcare systems, and another 73 countries have pledged to develop low carbon, sustainable health systems.[18] Healthcare systems will also need to adapt to meet increased demands caused by direct and indirect health impacts of climate change, and to ensure that healthcare facilities can withstand extreme weather events such as flooding and heatwaves, alongside (where relevant)

rising sea levels. For example heatwaves in 2022 led to widespread elective surgery cancellations in the UK.[36] Improving preparedness for climate change may help reduce the impact on surgical care provision.

## 1.2 The environmental impact of surgical care

An estimated **313 million surgical procedures were performed worldwide in 2012**, representing a one-third increase in volume over eight years.[37] This upward trend has been disrupted in recent years by cancellations and delays to planned elective surgical care relating to the COVID-19 pandemic.[38]

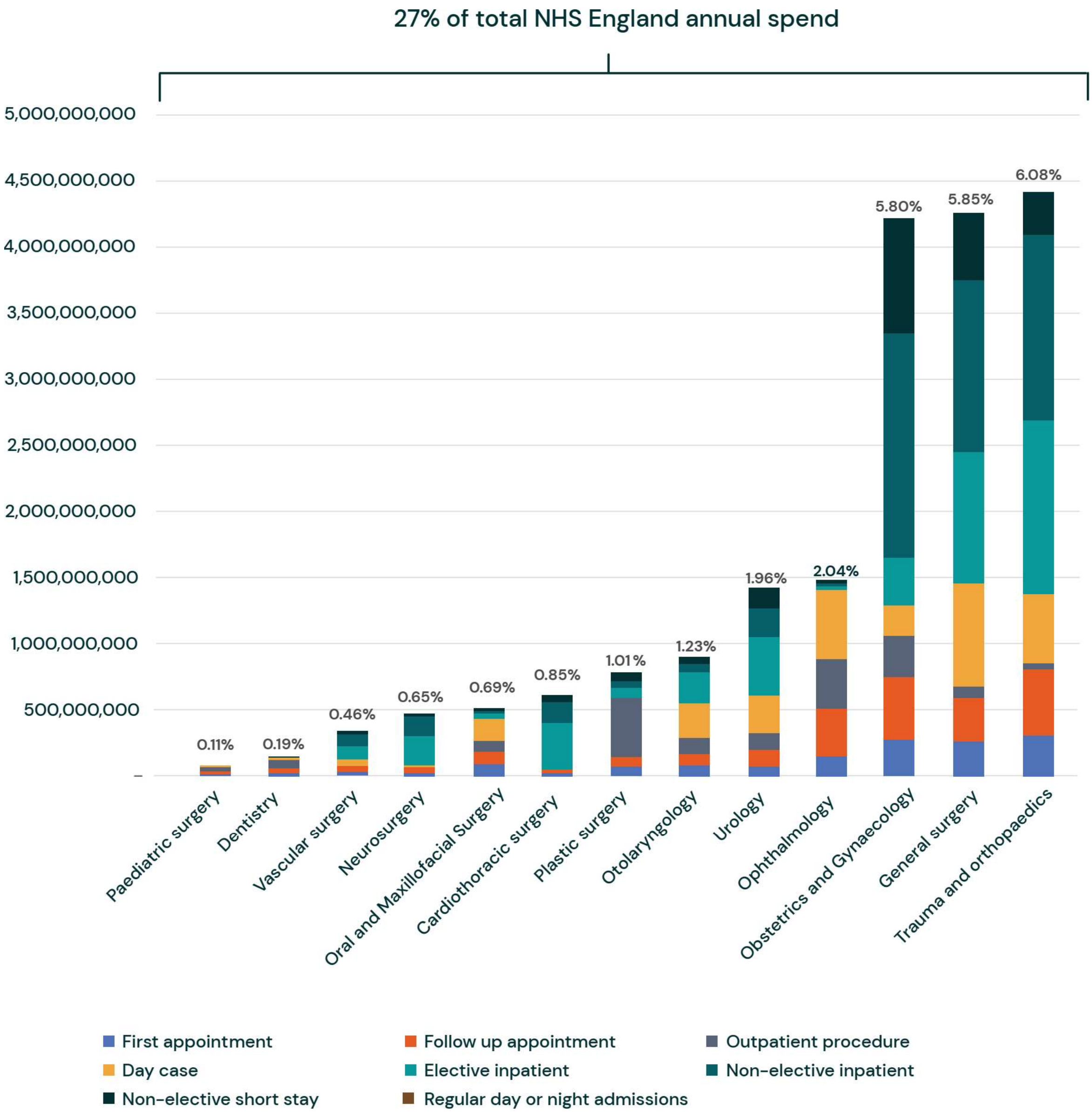
Surgical volume is dependent on how surgical 'procedures' are defined, for example between 2009 and 2014 an estimated 1.5 to 7.9 million procedures (at a cost of £5.6 to £10.9 billion) were performed each year in the UK, with lower figures derived using a 'restrictive' categorisation of a procedure (only major procedures), and higher for an 'inclusive' categorisation (including minor surgery, interventional radiology procedures and diagnostic endoscopies).[39] The total cost of surgical procedures (using the higher figure, but excluding upstream outpatient appointments and investigations, or downstream follow-up and management of complications) was previously estimated to account for **9.4% of the total NHS budget**.[39]

The scope of surgical care extends beyond operations and encompasses surgical patient pathways. Based on NHS England financial spend in 2019/2020,[40] (analysis in Appendix 2), we estimate that surgical care including outpatient appointments, procedures, and inpatient admissions cost £19.5 billion; this amounts to 27% of the £72.6 billion NHS England total spend on acute, community, ambulance and mental health providers in the financial year. Applying this proportionately to the 16.3 million tonnes of $CO_2e$ associated with these areas in 2019,[22] we estimate that the carbon footprint of surgical care in England totalled 4.8 million tonnes of $CO_2e$ in 2019. Assuming the same carbon intensity of surgery per person in the population across other UK nations, we estimate that in 2019 the carbon footprint of surgical care in Northern Ireland was 162 kilotonnes $CO_2e$, in Scotland was 468 kilotonnes $CO_2e$ and in Wales was 270 kilotonnes $CO_2e$. The summated estimate of the **carbon footprint of surgical care in the UK in 2019 is therefore 5.7 million tonnes of $CO_2e$**. To offset this would require planting of over half a million hectares of forest, an area more than triple the size of London.

Figure 2 breaks down the NHS England annual spend by surgical specialty in the 2019/20 financial year. The three specialties with highest financial spend were trauma and orthopaedics (6.1% NHS England annual spend), general surgery (5.9%), and obstetrics and gynaecology (5.8%). Across all surgical specialties, when broken down by type of financial spend:

- 7% related to 9.7 million first outpatient appointments
- 11% to 17.4 million follow-up appointments
- 7% to 9.8 million outpatient procedures
- 16% to 3 million day-case procedures
- 22% to 821,000 elective inpatient admissions
- 26% to 1.1 million non-elective long stay inpatient admissions
- 11% to 2 million non-elective short stay inpatient admissions

**Figure 2: Annual spend on surgical care in NHS England, 2019/20**




*Based on NHS England national cost collection, financial year 2019/2020.[40] Percentage above bars indicates proportion of total NHS England annual spend on acute, community, ambulance and mental health providers*

## The operating theatre

The operating theatre is a resource-intensive area of a hospital, using large quantities of single-use products (which typically generate around one-fifth of total hospital waste),[41] and is three to six times more energy intensive than the rest of the hospital.[42] A study examining operating suites in Canada, the United States of America (USA), and the UK estimated that a **typical operation** had a carbon footprint of 146-232 kg $CO_2e$,[42] comparable to emissions associated with driving **400-650 miles** in an average petrol car.[43] The same study found that a typical operating department in a large UK hospital generated over 5,000 tonnes $CO_2e$ per year,[42] equivalent to driving an average petrol car 580 times around the Earth.[43]

**The principal components that make up the carbon footprint of an operating theatre are:**

- Anaesthetic gases
- Reusable and single-use products
- Energy associated with the maintenance of the theatre environment (heating, ventilation, air-conditioning, lighting) and other electronic equipment
- Water
- Pharmaceuticals
- Patient and staff travel
- Capital goods
- Hospital infrastructure

The relative contributions of each of these components will vary in different settings and with different operations. Reviews report the biggest contributors to the carbon footprint (**carbon hotspots**) of operations to be **anaesthetic gases, energy usage**, and **products** used in surgery.[44,45]

# 1.3 Labour rights abuses in surgical products

In addition to the environmental impact of surgery, reports over the last fifteen years document cases of **labour rights abuse** in the manufacture of products used in healthcare, including surgical care in the NHS. This includes:

- **Sweatshop** and **child labour** in the manufacture of both disposable and reusable steel surgical instruments and laryngoscope blades in Pakistan (Figure 3)[46-48]
- Forced migrant labour in the manufacture of gloves in Malaysia[49] and Thailand[49,50]
- State-sponsored Uyghur and North Korean forced labour in the manufacture of masks and gowns in China[51,52]
- Labour rights violations in the manufacture of surgical masks in Mexico,[53] nurse uniforms in India,[54] and surgical drapes in Thailand[55]
- Likely labour rights harms in the manufacture of electrosurgical equipment, given known issues in electronics supply chain[56]

A lack of transparency in supply chains makes it difficult to accurately qualify labour risk in products used in surgical care, but risk is high for high volume low-complexity products, usually sourced at low price from countries known to have weak legislation, policy, and track record in protecting workers.[57-59] Purchasers always consider value for money, but it is often the case that little consideration is given to the conditions in which the products are made, the impacts on the people who make them, or the environmental implications for manufacturing countries.[59] Practices of procuring **cheap disposable healthcare products drive GHG emissions and environmental degradation** at sites of material extraction and manufacture, as well as significantly raising the **risk of labour rights harm**.[59-61]

Over the last decade, increasing regulatory efforts have been made at advancing the ethical procurement of healthcare products globally, ranging from the implementation of suppliers' codes of conduct to import bans. Developments in the UK include the Modern Slavery Act 2015[62] and the Health Care Act 2022[63,64] which require purchasers to obtain assurances regarding labour standards in the products they procure.

These legislative and regulatory initiatives have led to some demonstrable improvements, but serious labour rights harms persist[48,50] because the uptake, enforcement, and monitoring of socially sustainable procurement processes has not been widespread.[59] One reason for this is the complexity and **limited transparency** in multi-tier surgical value chains, which often limits procurers' ability to monitor standards and verify whether suppliers are meeting due diligence requirements.[48,57,65] Evidence also suggests that only a small fraction of contract breaches result in sanctions.[58]

Advancing a socially sustainable model for surgical products requires:

- **Labour rights protection embedded** in purchasing decisions[49]
- Supply chain transparency[66]
- Collaborative buyer-supplier-manufacturer relationships[67]
- A clear system of rewards and sanctions[57]

These strategies are also essential for supporting the transition towards greener products used in surgical care.

**Figure 3: Manufacture of steel surgical instruments in Sialkot, Pakistan**

*Photo credit: Martin Kunz*

# 1.4 Principles of sustainable healthcare and the triple bottom line

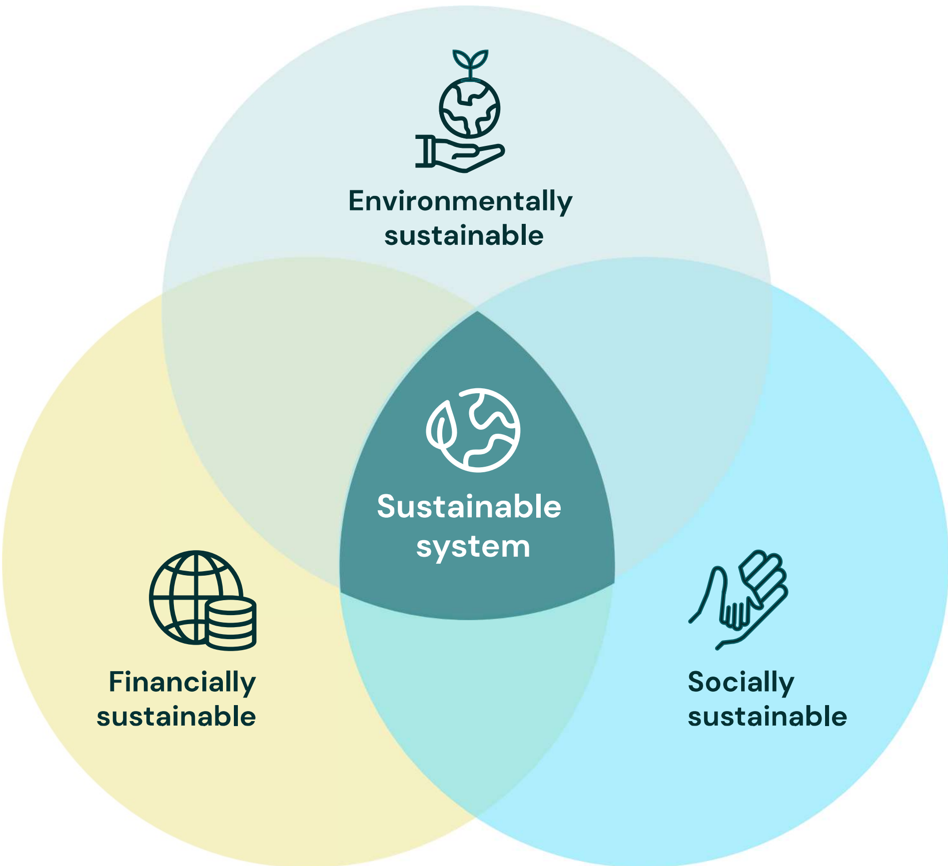
The UN 2030 Agenda for Sustainable Development aims to provide a 'shared blueprint for peace and prosperity for people and the planet, now and into the future'.[68] With this aim, 17 **UN Sustainable Development Goals** have been set, illustrating the complex interdependence between improving health and wellbeing, reducing inequality, environmental sustainability, and economic prosperity.[68]

'**Doughnut economics**' is another conceptual framework used to guide sustainable use of resources,[69] which encourages humanity to operate in the safe and just space between meeting basic social needs (in line with the UN Sustainable Development Goals),[68] whilst not exceeding the maximum ecological ceiling (which can be defined by the planetary boundaries previously discussed).[3]

Another core concept used to frame sustainable healthcare is the '**triple bottom line**', which encompasses the environmental, social, and financial costs of human activities[70] (alternatively referred to as the three Ps of people, planet, profit). This considers systems to be sustainable only where the three considerations intersect (Figure 4).[70]

We recognise that the triple bottom line framework has some limitations, including in evaluation (for example to provide valid measures for each pillar of sustainability), in practical application (for example where priorities to provide safe and high quality clinical care may conflict with other goals), and in strategic prioritisation (for example where investment in whole system change is more important than short term fixes).

**Figure 4: Triple bottom line of sustainability**




In line with these concepts, 'sustainable healthcare' is defined in this report as the provision of healthcare in a manner which meets health and wellbeing needs without direct or indirect negative impact on the health (or potential to provide healthcare) of populations separated by socioeconomic status, geography, or time. This report focuses on the environmental element of sustainable healthcare, with the definition extending to respect non-human life, and the term 'sustainability' and 'sustainable' are used hereon in to refer to environmental sustainability.

## Section recommendations

| Recommendation | Short term | Long term | Stakeholders |
|---|---|---|---|
| **R1.1**<br><br>Raise awareness of links between human and planetary health, and sources of greenhouse gas emissions in surgery | Have conversations with colleagues, patients[a,b]<br><br>Share Green Surgery report with colleagues[a] | Develop educational resources[c] | Healthcare professionals[a]<br><br>Patients[b]<br><br>Educators[c] |
| **R1.2**<br><br>When designing healthcare interventions, consider impact on environmental, financial, and social sustainability whilst maintaining or improving patient and population outcomes | Consider sustainability within audit, quality improvement, and research projects[a] | Consider sustainability at all stages of surgical care delivery, including upstream supply chain and supporting services[a,d,e,f] | Healthcare professionals[a]<br><br>Healthcare provider management teams[d]<br><br>Supporting services[e]<br><br>Industry[f] |

*Note: Letters in superscript after each short and long-term recommendation correspond with letters after each stakeholder group, indicating the group(s) with primary responsibility. This applies to all subsequent Section Recommendations in the Report.*