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Review

Sustainable Anaesthesia: How to Make a Difference

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Abstract

Climate change threatens human health; however, healthcare itself is an important contributor to our changing climate. Emissions of the major greenhouse gas carbon dioxide take place at every stage of a patient's healthcare journey, presenting numerous mitigation opportunities. Principles of sustainable healthcare should be employed at individual and organisational levels, with a particular emphasis on improving patient health before intervention becomes necessary to reduce overall population demand for healthcare. This necessitates patient empowerment through choice of treatments and lifestyle changes; clinicians should use patient encounters as opportunities for health promotion. Providing high-quality care at the right time, prioritising getting care right the first time and avoiding complications are key to reducing the environmental impacts of healthcare. Anaesthetists have a role in improving healthcare sustainability by improving their climate literacy, following the latest guidance on the most sustainable anaesthetic techniques, and minimising waste of medications, equipment, energy, and water. The Royal College of Anaesthetists has made progress to address environmental sustainability, prioritising both 'greener' speciality practice and its own environmental footprint. This article aims to guide clinicians and healthcare organisations in practising sustainable healthcare, with particular focus on anaesthetic practice in the UK.

Keywords: anaesthesia; carbon footprint; environmentalism; environmental impacts

1. Introduction

The World Health Organisation [1] recognises climate change as the single biggest health threat facing humanity, leading to thousands of additional deaths, and threatening to widen existing health inequalities. Large-scale action is urgently needed to reduce global carbon emissions and their climate impact to protect both people and planet [2].

Importantly, we must acknowledge the paradox that exists whereby climate change is bad for health, yet healthcare itself is a contributor. The burning of fossil fuels leads to the release of carbon dioxide (CO_2), the most important anthropogenic greenhouse gas (GHG), with resultant warming of the planet. Healthcare is a major source of CO_2, via transport and freight, buildings and infrastructure, and consumables and waste. This consideration has led to the National Health Service (NHS) committing to net-zero carbon emissions from direct patient care by 2040, with inclusion of the supply chain by 2045 [3]. Additionally, the Health and Care Act 2022 places a duty on NHS bodies to consider climate change and the natural environment in all programmes of work and act to support targets set out in the Climate Change Act 2008 and the Environment Act 2021.

Healthcare organisations are working to tackle the challenges of maintaining healthcare services whilst minimising environmental harm. In this context, the Centre for Sustainable Healthcare has published principles of sustainable healthcare [4]. This article focuses on the application of these principles to the speciality of anaesthesia and suggests how the World Federation of Societies of Anaesthesiologists guidance on the principles of environmentally sustainable anaesthesia can be applied to UK practice [5].

2. Climate Change, Carbon Dioxide Emissions and Health

Climate change and environmental degradation can be viewed as determinants of health, with wide-ranging health impacts from direct effects (e.g., heat stress) and indirect effects (e.g., increased communicable disease spread due to mass migration). In the UK, the impact of human-made air pollution is equivalent to 28,000–36,000 deaths per year, with links to cardiovascular and respiratory disease, including lung cancer and exacerbation of asthma [6]. The resultant increase in hospital admissions and premature deaths also increases demand on the NHS. For healthcare services to survive the climate crisis, sustainability must also include climate adaptation; we must incorporate systems to protect the services themselves from the impacts of climate change.

Healthcare organisations face challenges when approaching their 'carbon footprints' and how they achieve 'net-zero'. This is because the concept of net-zero applies chiefly to CO_2 emissions, yet all industries and individuals emit a variety of different GHGs, with varying

Table 1. The principles of sustainable healthcare, as per the Centre for Sustainable Healthcare, and how they can be applied to anaesthesia.

Principle	Description	Examples in anaesthesia
Prevention	Promoting health, preventing disease, and reducing healthcare needs.	Identifying alternatives to surgery, pre-operative optimisation and prehabilitation, reducing pain and post-operative nausea and vomiting.
Patient empowerment	Patients are taking a bigger role in managing their own health and healthcare.	Discussing anaesthetic options including local/regional/general anaesthesia; facilitating patient discussion and decision-making for non-surgical options; discussion of risk stratification; informing on environmental impacts of options; offering smoking cessation and lifestyle advice.
Lean pathways	Streamlining care to reduce low-value activity and adding high-value services.	Improving theatre efficiency; reducing on-the-day cancellations; Getting It Right First-Time principles; one-stop pre-operative clinics; applying enhanced recovery principles; avoiding duplication in the peri-operative pathway.
Low-carbon care	Switching to low-carbon treatments, utilising digital technology and reducing waste of medication, consumables, and energy.	Using oral rather than intravenous drug preparations, e.g., paracetamol; reusable personal protective equipment; use of the CoolStick® instead of ethyl chloride spray to assess sensory blockade.

'potency' and atmospheric lifetimes. This is of relevance to anaesthesia since our current practice involves the use of volatile agents and nitrous oxide (a major GHG and ozone depleter). Life-cycle analyses use the simplified metric Global Warming Potential (GWP), and its derivative equivalent-CO_2 (CO_2e); however, these can give misleading results when including short-lived gases such as volatiles [7,8]. This problem has already been recognised within mitigation strategies for methane in agriculture (e.g., [9]). How we surmount the problem of collapsing multiple different gases onto a single scale, and how that information is used to make 'net-zero' mitigation strategies, is beyond the scope of this article. The important take-home message is that CO_2 remains the single greatest threat and must be the focus of sustainable healthcare, and therefore the focus of discussion in this article. In later sections, we will outline mitigation opportunities for anaesthetists.

However, planetary health goes beyond CO_2 emissions—nine planetary boundaries detail the safe operating space for humanity. These are: climate change; novel entities (including synthetic chemicals such as microplastics); stratospheric ozone depletion; atmospheric aerosol loading; ocean acidification; modification of biochemical flows (for example, nitrous or phosphorus cycles); freshwater change; land system change; and biosphere integrity [10]. Concerningly, 6 of these are thought to have already been transgressed [11]. All aspects of our natural environment are interlinked, e.g., a healthier ocean can help mitigate against atmospheric CO_2 [12] rises. Therefore, when considering sustainable practice in our drive for 'net-zero' CO_2, we must not lose focus on the other important contributors to the concurrent climate and ecological crises.

3. What Is Sustainable Healthcare?

The Royal College of Physicians recognises sustainability as a domain of quality in healthcare. They describe sustainability as follows:

"Sustainability should be viewed as a characteristic of healthcare which must run through and moderate other domains. Healthcare should be considered not only in terms of what can be delivered to an individual today, but also to the population in general and the patients of the future" [13].

The Centre for Sustainable Healthcare (CSH) has defined a framework of priorities describing four principles to bring about sustainable healthcare [4]. Anaesthetists can contribute to sustainable healthcare by addressing each of these, as illustrated in Table 1.

Sustainable care must be patient-centred, and patients should be involved in discussions on what sustainable healthcare looks like. To respect patient autonomy, healthcare professionals should include discussion of the environmental impacts of treatments as part of the consent process, known as "green informed consent" [14]. For example, an awake regional technique is a safe and appropriate approach for many surgeries, results in a swifter recovery and requires fewer resources. Adjusting both clinician and patient expectations takes time and communication, but in our experience, patients are keen to be involved in their care and tolerate awake procedures well when appropriately counselled. Indeed, research commissioned by the Health Foundation found more than four in five people are concerned about climate change and that the public would consider making changes to their own behaviours to support the NHS net-zero goal [15]. Research from NICE [16] also found that, when given a choice, members of the public commonly preferred more environmentally sustainable

care options. Importantly, the National Institute for Health and Care Excellence (NICE) also found that their participants universally supported approaches to environmental sustainability that enabled patient choice.

4. What Does Sustainable Anaesthesia Look Like?

Anaesthetists have an important role to play in tackling the climate emergency, making decisions daily which have environmental consequences. In 2021, a global consensus statement from the World Federation of Societies of Anaesthesiologists provided guidance on the principles of environmentally sustainable anaesthesia, see below [5]. Whilst these principles are useful to embed sustainability across anaesthetic practice, the need for this consensus to be internationally applicable has led to the principles being broad and lacking in specificity about what this might look like in a particular setting. The authors will consider how these principles apply to UK anaesthetic practice and individual clinicians below.

World Federation of Societies of Anaesthesiologists principles of environmentally sustainable anaesthesia

1. Minimise the environmental impact of their clinical practice.
2. Use environmentally preferable medications and equipment when clinically safe to do so.
3. Minimise the overuse/waste of medications, equipment, energy, and water.
4. Incorporate environmental sustainability principles within formal anaesthesia education.
5. Embed environmental sustainability principles within anaesthesia research and quality improvement programs.
6. Lead environmental sustainability activity within their healthcare organisations.
7. Collaborate with industry to improve environmental sustainability.

4.1 Minimise the Environmental Impact of Clinical Practice

As already discussed, the emission of CO_2 is the largest anthropogenic contributor to global warming. Every CO_2 emission will accumulate and contribute to global warming; therefore, any avoided emission is valuable and worthwhile. Moreover, when considering changing anaesthetic practice, it is imperative that no change results in increased CO_2 production.

Avoiding CO_2 emissions can be done in many ways, but the most significant of these will be in reducing the amount of healthcare delivered. Anaesthetists undertaking perioperative medicine have important opportunities to reduce healthcare activity by ensuring minimal unplanned admissions through adequate management of pain and post-op nausea and vomiting, applying 'Getting It Right First-Time' principles and through identification of high-risk patients, with evidence-based joint decision making to avoid unnecessary surgeries. The perioperative journey also provides opportunities to make every contact count by promoting health. For example, offering smoking cessation and lifestyle advice, such as exercise and diet, will reduce wider health service activity over the long term. Case study 1 shows an example of how perioperative lifestyle intervention strategies can have long-term impacts on patient health. Enhanced recovery principles should be applied wherever clinically appropriate. Importantly, minimising the environmental impact of clinical practice goes hand in hand with providing high-quality care, resulting in reduced length of stay, fewer complications, and overall better patient outcomes.

Case study 1: Smoking Cessation—Making Every Contact Count.

A University-Affiliated hospital in Ontario, Canada, undertook a randomised controlled trial to assess the impact of preoperative smoking cessation intervention. Patients were randomised in the preadmission clinic, at least 3 weeks preoperatively. Those in the intervention group received (1) brief counselling by the preadmission nurse, (2) brochures on smoking cessation, (3) referral to the Canadian Cancer Society's Smokers' Helpline, and (4) a free 6-week supply of transdermal nicotine replacement therapy. Postoperatively, smoking cessation was reported in 22 patients (28.6%) in the intervention group compared with 8 patients (11%) in controls at 30 days. At one year, smoking cessation occurred in 25% of the intervention group, compared with 8% of control patients. The team found that patients randomised to the intervention group were 2.7 times more likely to achieve long-term cessation than those in the control group [17,18].

4.2 Use Environmentally Preferable Medications and Equipment

This might also be viewed as avoiding using environmentally damaging medications and equipment. For example, nitrous oxide is a long-lived GHG and is rarely essential to clinical practice. Evidence shows most nitrous oxide in the UK is wasted prior to reaching any patients due to leaks from pipeline infrastructure and poor manifold management practices [19]. The Royal College of Anaesthetists (RCOA) recently published a joint consensus statement with other national bodies advocating for the removal of pipeline nitrous oxide, with a shift to cylinders only [20]. If nitrous oxide use is required for best patient care, low fresh gas flows should be used. Case study 2 shows an example of the environmental and financial savings that can be made through switching from manifold to cylinder nitrous oxide.

Nitrous oxide cracking technology is available to convert scavenged nitrous oxide gas into non-harmful nitrogen and oxygen. Deciding whether to implement this technol-

ogy is complex, as consideration must be given to the embedded environmental impact (carbon footprint, water use, energy use, etc.) of equipment production and installation. Where nitrous oxide use is low, introducing this technology may not be of overall environmental benefit. In contrast, the widespread use of Entonox in obstetric practice may present a mitigation opportunity. A particular barrier to implementation is the need for financial investment, which will be discussed later.

There are also opportunities to apply the principle of low-carbon care through the choice of equipment. Clinicians should consider reusable options where available, for example, switching from ethyl chloride to using The CoolStick® to assess sensory blockade with regional anaesthesia. This may have both environmental and financial savings, as shown in Case study 3.

Case study 2: Reducing Nitrous Oxide Waste.
At King's College Hospital, London, nitrous oxide was rarely used in most routine procedures. However, the centralised supply from large cylinders (known as manifolds) was found to exceed the clinical demand significantly, as they are susceptible to leaks. The hospital transitioned to small portable cylinders instead. The use of portable cylinders reduced monthly nitrous oxide emissions by 55% (from 333 tonnes to 150 tonnes) and annual financial costs by approximately 80% (from £12,000 to £2500 ($15,986–3361)). Four manifolds have already been decommissioned [21].

Case study 3: Switching From Ethyl Chloride Spray to The CoolStick®.
Hampshire Hospitals NHS Foundation Trust undertook a series of projects aiming to reduce the carbon footprint of arthroplasty procedures. One of the interventions was replacing the disposable anaesthetic cooling spray ethyl chloride with the reusable CoolStick®.The team found the CoolStick® was non-inferior in assessing the level of sensory block following regional anaesthesia. This switch to reusable equipment saved 6240.91 $kgCO_2e$, with an annual financial saving of £10,621.56 ($14,150.44) [22].

4.3 Minimise the Overuse/Waste of Medications, Equipment, Energy, and Water

Whilst not emitting long-lived GHGs is the best approach, it cannot be wholly avoided since healthcare will always be required. Anaesthetists should ensure to apply the principles of the waste hierarchy, i.e., "reduce, reuse, recycle", to minimise the environmental impacts, with reducing resource usage being the most preferable. Reduction of resources should include only opening what is required, considering the supply of emergency drugs in prefilled syringes to avoid regular disposal of unused drugs and syringes, as shown in Case study 4, and considering techniques which utilise fewer resources (e.g., using local or awake regional anaesthesia). Energy wastage can be reduced through turning off energy-hungry equipment when not in use, e.g., anaesthetic gas scavenging systems, theatre heating and ventilation, forced air warmers and radiant overhead heaters [23]. Simple interventions, such as using a theatre shutdown checklist, can encourage staff to reduce energy usage, as shown in Case study 5. Reusable equipment should be considered where possible, and anaesthetic departments could explore utilising remanufactured equipment. Research remains to be done to unpick the impact of commonly used pharmaceuticals on water and ocean health. It is vital that unused and waste pharmaceuticals are disposed of via a dedicated pharmaceutical waste stream, and adaptation of this waste stream in theatre suites and beyond should be strongly encouraged in all hospitals.

Case study 4: Prefilled Syringes for Emergency Drugs.
A team at East Kent Hospitals University Foundation Trust has undertaken a project to analyse the environmental and financial costs of using ampoules vs. prefilled syringes for emergency drugs: metaraminol, ephedrine, atropine, propofol (emergency use) and glycopyrronium. At just one hospital site (Queen Elizabeth the Queen Mother), which has 9 theatres, they estimated 9655 ampoules are wasted (i.e., prepared but not used), with a total cost of £22,628.22 ($30,154.55). Considering both used and wasted metaraminol, ephedrine, and atropine ampoules cost the Trust £44,359.68 ($59,114.08) annually, whereas the projected costs of using prefilled syringes that are only opened when required are £34,452.60 ($45,915.79)—a financial saving of £9907.08 ($13,203.39) per year.
They also estimated that 196.8 kg of waste is produced from emergency drugs annually, with a carbon footprint of 3372 $kgCO_2e$. They state switching to prefilled syringes also reduces this waste, and the associated cost and carbon footprint of its incineration [24].

Case study 5: Energy Saving Through Theatre Shutdown Checklist.
A team from Swansea Bay University Health Board aimed to increase switching off theatre equipment not required out of hours through compiling a "shutdown" checklist and poster for elective operating theatres. This included computers, anaesthetic machines, and anaesthetic gas scavenging systems. If all equipment were switched off overnight (13 hours), they estimated potential energy savings of 190,212 kWh per year, equivalent to 49,749 $kgCO_2e$, and financial savings of over £26,000 ($34,658) per year [25].

4.4 Incorporate Environmental Sustainability Principles Within Formal Anaesthesia Education

Including sustainability in anaesthesia education is extremely important as education plays a key role in altering behaviour and policy [26]. The Royal College of Anaes-

thetists (RCOA) demonstrated leadership when they included environmental sustainability in the 2020 curriculum update [27]. Clinicians should engage in planetary health and carbon literacy training, such as the Centre for Sustainable Healthcare courses [28], or Carbon Literacy for Healthcare e-learning [29]. This is particularly important as medical devices and pharmaceutical companies acknowledge the net-zero NHS goals and increasingly include reference to being 'green' or 'sustainable' in their product literature. Healthcare professionals need to be carbon literate to be able to spot dubious claims and 'greenwashing'. Anaesthetists can also access speciality-specific e-learning on environmental sustainability via RCOA [30].

4.5 Embed Environmental Sustainability Principles Within Anaesthesia Research and Quality Improvement Programmes

Anaesthetists may choose to undertake research and quality improvement projects (QIPs) which focus on environmental sustainability. The RCOA [31] Quality Improvement Compendium suggests projects aiming to reduce the carbon footprint of volatile anaesthetic use and to tackle waste through reduction and recycling initiatives. Whilst some of the suggestions made in the compendium are now outdated, it's suggested that specific interventions and examples of best practice make it a useful starting resource for clinicians. However, embedding environmental sustainability principles into research and quality improvement (QI) does not only include undertaking projects with a specifically "green" focus. Any project can be undertaken through the lens of sustainable quality improvement (SusQI). This approach assesses quality and value through the "triple bottom line", whereby outcomes are measured against environmental, financial, and social impacts [32]. The SusQI methodology was developed by the Centre for Sustainable Healthcare with the aim of embedding sustainability into current QI theory and practice. Clinicians should consider utilising this method in all QIPs and can find out more about it on the SusQI website and course [32].

4.6 Lead Environmental Sustainability Activity Within Their Healthcare Organisations

Practising sustainable healthcare is not only about individual choices made by clinicians; there must be infrastructure and support in place to facilitate making sustainable choices easy. Individuals must work in organisations which support and value sustainable practice, which in turn must be supported by their wider organisations and the national health strategy. This relies on the NHS and wider healthcare organisations showing leadership, leading by example with changes to their internal practice and publishing guidelines and policies to promote sustainable practice. Clinicians should engage with departmental and hospital leaders to bring about sustainable system change. Healthcare professionals are trusted voices within our society [33]; they should use their voice to advocate for sustainability within and beyond healthcare.

Looking to speciality leaders, the Royal College of Anaesthetists has made significant progress in its efforts to address environmental sustainability. They have established an Environmental Advisors Group, joined the UK Health Alliance on Climate Change and, in their recently published Environmental Strategy [34], declared a climate and ecological emergency. The College's strategic priorities focus on two key areas: promoting environmental sustainability in the speciality and working towards carbon neutrality within the organisation.

Their work with 'greener' anaesthetic practices within the NHS involves engaging with policymakers and supporting members in implementing sustainable healthcare practices. Efforts include promoting carbon literacy, aligning with NHS projects like Getting It Right First-Time (GIRFT), and addressing environmental impacts in guidelines and curricula. In addition to the nitrous oxide statement mentioned above, the College has issued a Joint Environmental Policy Statement with the Association of Anaesthetists [35] and collaborated on initiatives such as the decommissioning of desflurane [36] and the development of a Green Theatre Checklist [37]. Regular sessions on environmental sustainability have been incorporated into events.

The second priority of reducing the College's own carbon footprint involves measuring its carbon emissions and committing to remeasuring in 2027 to assess progress. A Climate Change Adaptation Plan will be developed, and the provision of the College estate will be informed by environmental considerations. Regarding the College finances, they have divested from fossil fuels and have had commitment from their pension providers to achieving net-zero emissions. Travel emissions are being tackled by adopting a hybrid model of virtual and in-person meetings, encouraging staff to use active transport by offering cycle-to-work schemes, and implementing a sustainable Travel & Subsistence Policy. Additional measures include switching to a renewable energy provider, revising their procurement policy to prioritise low-carbon options (e.g., environmentally conscious catering within College buildings), virtual written exams to reduce travel, digital-only publication formats and adopting paperless workflows.

4.7 Collaborate With Industry to Improve Environmental Sustainability

It is notable that much of the information regarding the environmental impacts of new technologies is unavailable to the public. Manufacturers should share transparent life cycle analyses of their equipment to aid in decision-making, such as in the NHS [38] and Evergreen sustainable supplier assessment [39].

Suppliers should also take responsibility for providing cost analyses for their equipment, as this may be complex and is certainly outside the remit of most clinicians.

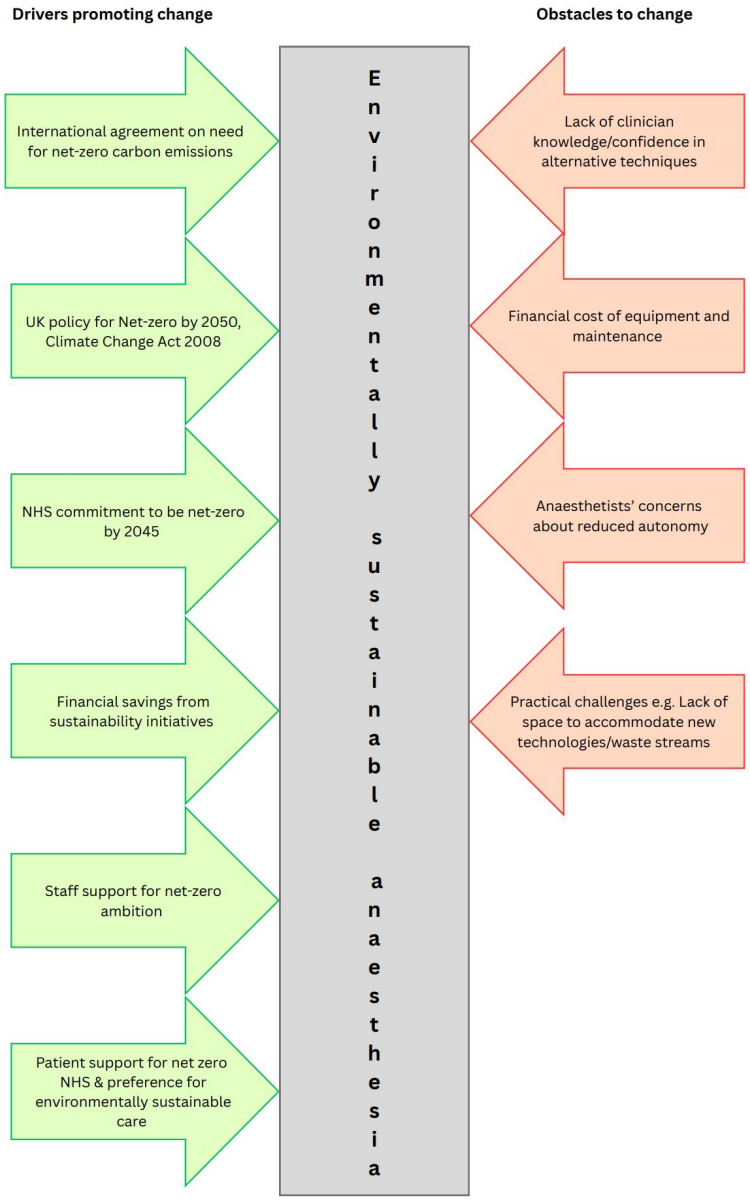

Fig. 1. Forcefield analysis of drivers towards change and obstacles against change in relation to environmentally sustainable anaesthesia. Drivers towards sustainable anaesthesia include international agreement on need for net-zero carbon emissions [45]; UK policy for net-zero by 2050 as per the Climate Change Act 2008; the National Health Service (NHS) commitment to be net-zero by 2045 [3]; financial savings from sustainability initiatives; staff support for net-zero ambition [43]; and patient support for net-zero NHS [15] and preference for environmentally sustainable care [16]. Obstacles to sustainable anaesthesia include lack of clinician knowledge or confidence in alternative techniques; the financial cost of equipment and its maintenance; anaesthetists' concerns about reduced autonomy over their clinical practice; and practical challenges, for example, a lack of space to accommodate new technologies and dustbins for multiple waste streams. Figure created using Canva (https://www.canva.com/zh_cn/).

An example is in the consideration of reusable equipment. Where equipment is used frequently, there is a decrease in the 'per use' environmental costs and need for manufacture and disposal of new equipment, and the GHG these processes generate. Where equipment is used infrequently and the financial and environmental costs of cleaning may be high (e.g., high temperature sterilisation), the value per use may be lower and single-use items may then be preferable.

NHS organisations should work with suppliers to reduce waste from equipment and find circular solutions to necessary waste, such as recycling schemes. Case study 6 gives an example of how this can be achieved through working with industry.

When considering equipment and medications, it is prudent to remember that around 60% of the NHS's total carbon equivalent emissions are due to the global na-

ture of its supply chain, and approximately 80% of goods supplied to the NHS arrive by ship [3]. It follows that the NHS cannot achieve 'net-zero' without consideration of how our goods arrive, given the estimated direct impact of the global shipping industry is around 1 billion tonnes of CO_2 per annum [40]. Engagement with organisations such as Cargo Owners for Zero Emission Vehicles (CoZEV) and Zero Emission Maritime Buyers Alliance (ZEMBA)—either directly or indirectly via the NHS's vast network of suppliers—will form an important part of reducing this indirect impact.

Case study 6: Working With Industry.
University College Hospitals National Health Service (NHS) Foundation Trust has developed a recycling programme for single-use surgical items, which are often difficult to recycle because they are made of mixed materials. Delivered in conjunction with suppliers Johnson & Johnson MedTech and their partners MYGroup and Resourcify, the programme enables metal and plastic from suture foil packaging to be collected from theatres in special bins, themselves made from recycled plastic.
Waste management company, MYGroup, collect the waste and takes it to their facility, where it is separated into metal and plastic. The plastic is converted into 'MYBoard ™'—a material similar in consistency to plywood—used for construction, joinery, and furniture. Metal components are smelted back into aluminium for recycling into new products.
The project is expected to reduce waste previously destined for incineration by 215 kg per year [41].

5. Barriers to Sustainable Anaesthesia

The way services are organised and delivered within the NHS, along with the internal culture in each NHS organisation, is driven by numerous factors, including the influence of multiple stakeholders. These stakeholders have varied and different objectives and agendas, which can push and pull NHS services in competing directions, with conflict between delivering the highest standard of care and remaining financially viable within a fixed budget. Delivering environmentally sustainable care may be seen as another conflicting factor. However, this draws a false dichotomy between high-quality care and sustainable care when they, in fact, go hand-in-hand. Sustainable care is, by its nature high quality care, focusing on efficiency, preventing ill-health, and prioritising getting care right the first time. Understanding this is important when trying to sway hearts and minds in a resource-constrained system. Due to greater efficiency, sustainable care need not conflict with the financial bottom line, though some initiatives will require up-front investment, e.g., new technologies and reusable equipment. The cost of initial investment may be a barrier to implementation, with difficulties in finding the initial funding when departments work from an annual budget. Departments should consider ring-fencing money saved through sustainability initiatives to reinvest in such programmes. It may be that funding for some initiatives will only become a reality if financial penalties are applied to Trusts failing to meet their net-zero obligations.

Changing practice towards environmentally sustainable anaesthesia will require alterations to aspects of NHS organisations, alongside formal training for staff in alternative ways of working. The culture of anaesthetic departments needs to be changed to make the transition to environmentally friendly practices as smooth as possible. Culture change can be complicated due to differing perspectives on what environmentally sustainable anaesthesia looks like, or whether this is even an important goal. Change makers should pay close attention to factors influencing individual clinician behaviour, for example, using the Capability, Opportunity, Motivation-Behaviour (COM-B) model of behaviour, as resistance from this cohort could sabotage changes on the frontline [42]. Leaders must ensure staff are comfortable with new ways of working and are prepared to provide ongoing training. This is especially important in healthcare, where failure of staff to adapt to new ways of working may cause patient harm. A national survey revealed nine in ten NHS staff support net-zero targets [43], and this must be harnessed at the local level, such as networks connecting interested individuals and allowing time to plan and implement changes. Individuals and departments are encouraged to use validated change management tools, such as the NHS England Sustainable Improvement and Horizons Teams Change Model Guide [44]. The force-field analysis demonstrates how factors influence the proposed change towards environmentally sustainable anaesthesia (Fig. 1, Ref. [3,15,16,43,45]).

6. Conclusion

Healthcare is an essential service, the quality of which impacts the lives of all people. As such, it is imperative that healthcare is designed, planned, and carried out in a sustainable way. Sustainability in this context must go further than financial viability and efficiency, and include wider society and the natural environment. Our health is dependent on natural systems, so it is nonsensical to adopt an approach to healthcare that fails to value planetary health or to respect planetary boundaries. We must recognise that what is good for the planet is also good for our health and wellbeing. Key priorities include reducing the emissions of CO_2 and other long-lived GHGs. This means using less, only when necessary, and practising more efficiently. We must reduce activity across healthcare with an emphasis on improving patient health before medical intervention becomes necessary. This necessitates patient empowerment, treating every patient encounter as an opportunity for health promotion and providing high-quality care at the right time. The NHS is one of the largest employers in Europe. If we all

make sustainable choices, collectively we can have a positive impact on planetary health and climate change.

Key Points

- Carbon dioxide remains the single greatest threat and must be the focus of sustainable healthcare, which means using less, only when necessary, and practising more efficiently.
- Principles of sustainable healthcare should be implemented at both the individual and organisational levels, encompassing prevention, patient empowerment, lean pathways, and low-carbon alternatives.
- Reducing overall healthcare activity by empowering patients through choice of treatments and promoting lifestyle changes is essential to reducing the environmental impacts of healthcare.
- Clinicians should use every contact with patients as an opportunity for health promotion.
- Providing high-quality care at the right time, prioritising getting care right the first time and avoiding complications are key to reducing the environmental impacts of healthcare.
- Anaesthetists should engage with carbon literacy training and follow guidance for practising environmentally sustainable anaesthesia, including the use of environmentally preferable medications and equipment, and minimising overuse and waste of medications, equipment, energy, and water.

Availability of Data and Materials

All the data of this study are included in this article.

Author Contributions

LB, LF, MES, and PJS made substantial contributions to the design of the work. All authors contributed to writing the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

All authors are members of the Royal College of Anaesthetists Environmental Advisory Group. Additionally, LF is a previous Chief Sustainability Officer's Clinical Fellow with NHS England, and PJS is a member of Royal College of Anaesthetists Council. Fig. 1 was created using Canva (https://www.canva.com/zh_cn/). The authors have no financial or personal relationship with Canva, and the use of this tool does not imply any endorsement.

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