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Carbon footprint reduction of the operating room: tools to mitigate the environmental impact of surgical practice

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Citation

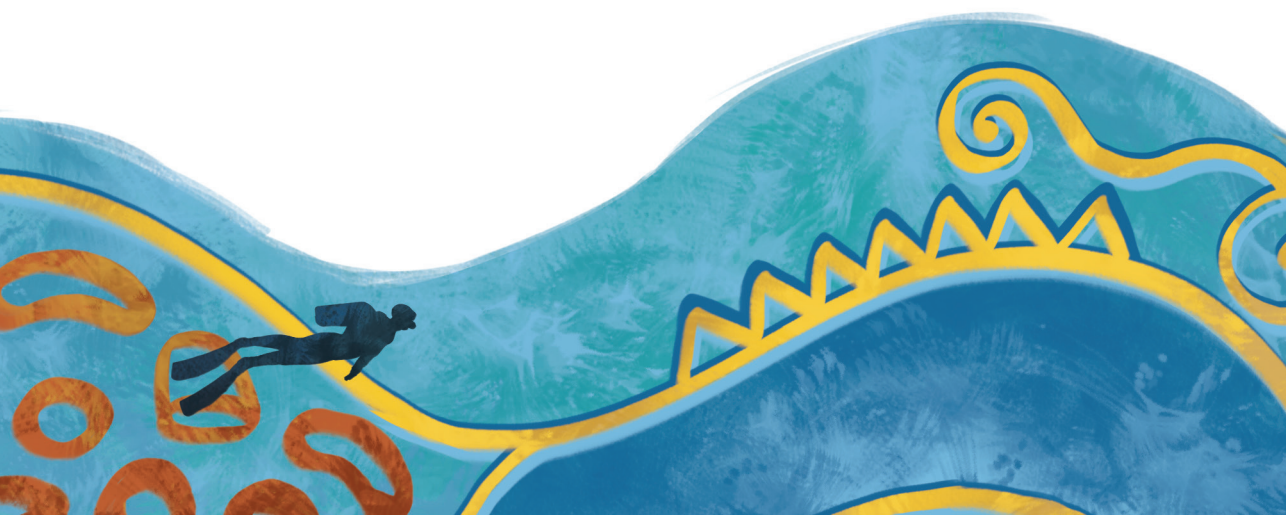
Friedericy, H. J. (2026, September 30). *Carbon footprint reduction of the operating room: tools to mitigate the environmental impact of surgical practice*. Retrieved from <https://hdl.handle.net/1887/4310441>

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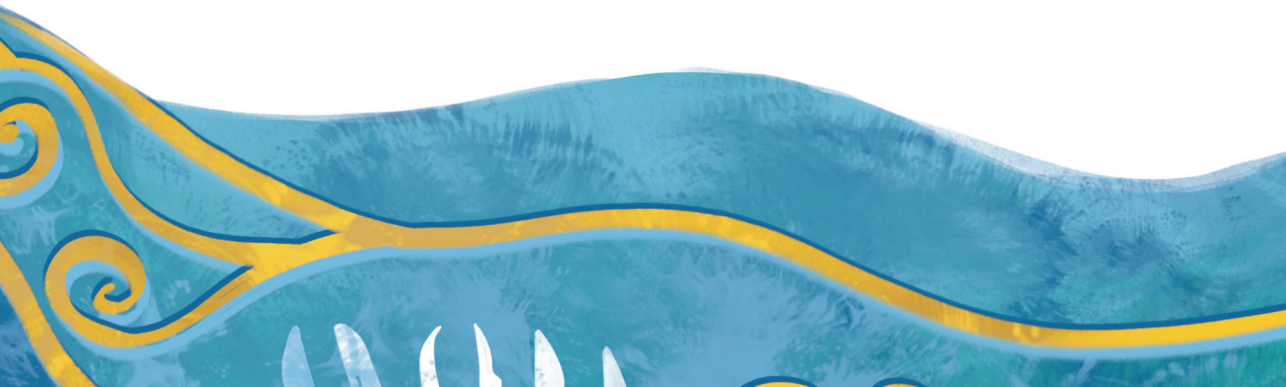
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CHAPTER 1

General Introduction



General Introduction



The era in which we currently live is typically referred to as the Anthropocene, the period of time marked by profound human influences, such as greenhouse gas (GHG) emissions, large-scale deforestation, and the spread of microplastics.¹ Although the term 'Anthropocene' is not officially recognised as a new epoch following the Holocene, it is considered an important transformative event in Earth's history.² It could be said that the Anthropocene began at the end of the 18th century. Analyses have shown that from that time onwards, there was an increase in the GHGs CO₂ and methane found in the air trapped in polar ice.¹ Since the 1950s, humanity's impact on the environment has accelerated, resulting in a dramatic exponential increase in the concentration of GHGs in the atmosphere that has resulted in a near 1.5 °C (above pre-industrial levels) increase of global temperature today.

Climate change is caused by global warming due to GHG emissions, and has major consequences for human well-being. Extreme weather conditions such as heat waves, extreme precipitation, and extreme droughts have undeniable consequences for human health and are increasingly claiming lives and harming people's health worldwide. These weather extremes cause heat-related deaths in vulnerable age groups, such as the very young and the elderly. Extreme drought threatens food and water security and increases the risk of wildfires. Changing climatic conditions are also increasing the risk of transmission of deadly infectious diseases such as dengue and tick-borne diseases (Figure 1).³ Paradoxically, the healthcare sector contributes significantly to GHG emissions such as CO₂ into the atmosphere and is therefore jointly responsible for the negative effects of climate change on public health.

It has recently been determined that the GHG emission of the global healthcare sector is 2.4 gigatonne CO₂-eq, which accounts for 4.4% of the total globally emitted GHGs.⁴ The healthcare GHG emissions per inhabitant across a sample of 36 countries in 2014 was 0.6 tonne CO₂-eq per capita. However, not all countries emit equally; high-income countries such as the United States, Luxembourg, Japan, Estonia, Slovakia, and the Netherlands were at the top of the list with more than 0.85 tonne CO₂-eq per capita. At the low end of the list were Turkey and Mexico with 0.23 and 0.13 tonne CO₂-eq per capita, respectively.⁵

Making healthcare more sustainable

The World Health Organization (WHO) acknowledges that climate change is one of the most serious global health threats of the 21st century and emphasises that decarbonising healthcare systems is essential to both mitigate climate change and protect public health. The WHO advocates, among other actions, that healthcare facilities must be

climate resilient and environmentally sustainable in order to achieve these goals.⁶ In the Netherlands, this ambition has been elaborated in the Green Deal for Sustainable Healthcare. This is an agreement between the Dutch Government and other partners for the implementation of sustainable plans. The Green Deal for Sustainable Healthcare 3.0 targets, among other things, to reduce CO₂ emissions by 55% by 2030 and to be climate neutral by 2050, as well as to reduce the consumption of primary raw materials by 50% by 2030 and maximise circularity in healthcare by 2050.⁷

Operating rooms (ORs), known for their high energy consumption, large consumption of goods, and significant waste generation, offer high-impact opportunities for reducing healthcare emissions. This places them at the heart of strategies for decarbonising hospitals with measures such as energy efficiency, pollution reduction, sustainable waste management and resource efficiency. To decarbonise healthcare efficiently it is important to assess baseline GHG emissions, set targets and monitor progress using universally accepted measurement and accounting methods.⁶

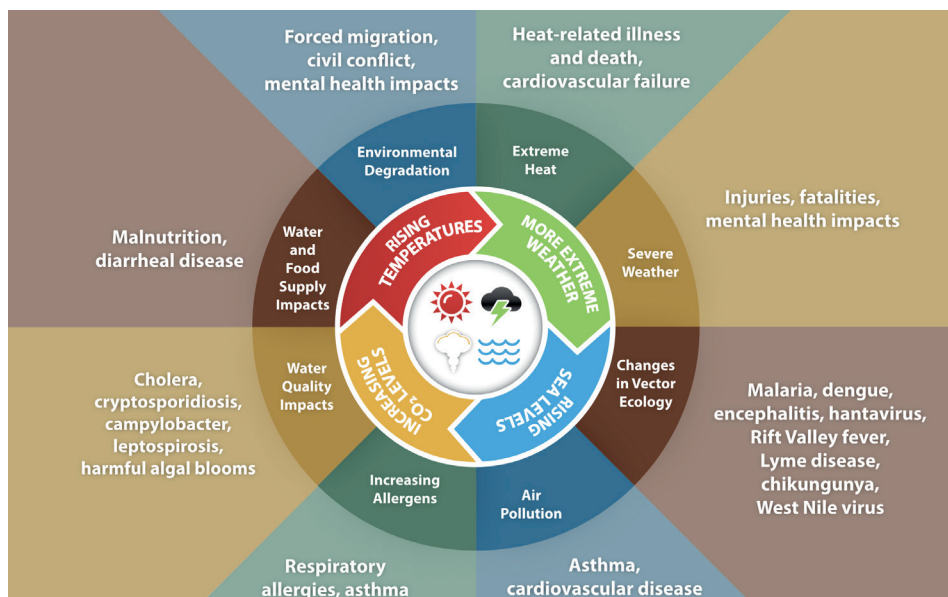


Figure 1. Impact of climate change on human health (Source: US Center for Disease Control and Prevention).



Measuring and accounting carbon emissions

Global warming is caused by an increase in GHGs such as carbon dioxide, nitrous oxide, methane, and fluorinated gases in the atmosphere. Because these gases absorb infrared light, they prevent heat radiation from the earth to space resulting in a rise in temperature (Figure 2).

To quantify the carbon emissions of a product, organisation, or activity, a carbon footprint can be calculated. A carbon footprint is defined as ‘the amount of direct and indirect CO₂ emissions that is caused by an activity, or collected during the life cycle of a product’.⁹ The calculation can be done by means of a life cycle assessment (LCA). With this ‘cradle to grave’ method, the environmental impact during the entire life cycle of a product is calculated from the extraction of raw materials to production, transport, use and waste disposal. Carbon footprint is expressed in CO₂ equivalents (CO₂-eq) which is a unit of measurement that is used to standardise the climate effects of various GHGs. For example, the emission of 1 kg of methane is equal to 25 kg CO₂-eq. Commuting 12.5 km to work in a car producing 170 g CO₂-eq km⁻¹, 5 days a week for 46 weeks a year (5,750 km) produces 1 tonne CO₂.⁸

The ‘Greenhouse Gas Protocol’ is the standard for reporting the carbon footprint of companies and organisations.¹⁰ According to this protocol, GHG emissions are categorised in three scopes: Scope 1 includes direct emissions; Scope 2 includes indirect emissions resulting from the generation of purchased electricity or heat; and Scope 3 includes all other indirect emissions resulting from the production of goods, waste processing and the travel movements of staff and patients (Figure 3).

The carbon footprint of the OR

Research on the carbon footprint of OR complexes shows that there are large absolute and relative differences between hospitals. The most important elements that contribute to the carbon footprint of an OR are: the emissions of inhalation anaesthetics (Scope 1), energy consumption by the heating, ventilation, and air conditioning (HVAC) system (Scope 2) and purchase of goods and the waste production (Scope 3).¹¹

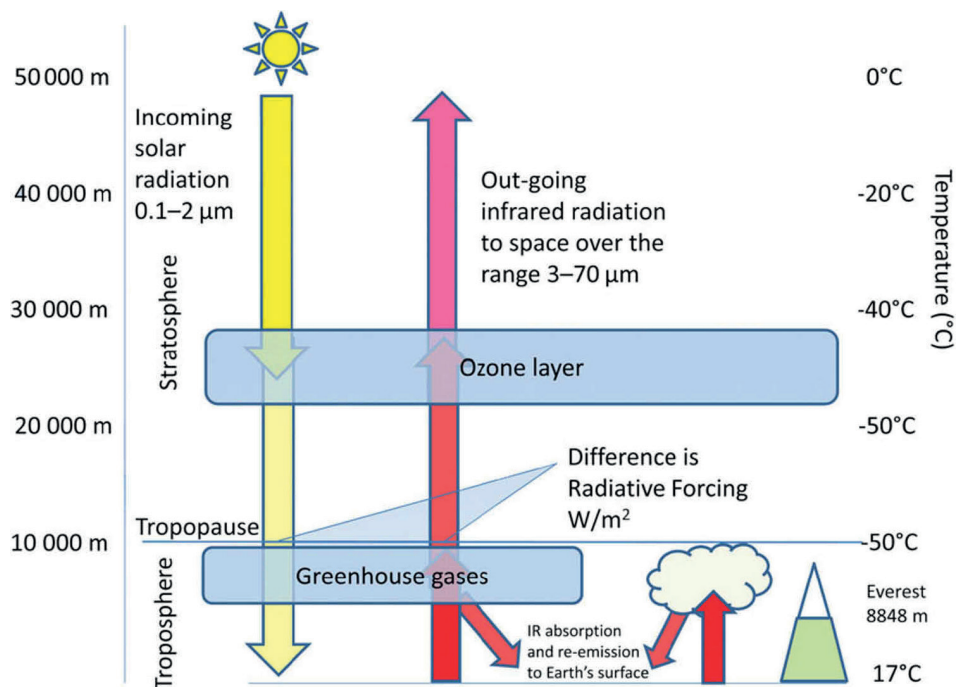


Figure 2. Simplified diagram of the Earth's energy balance. The difference between the incoming and outgoing radiation at the tropopause is called radiative forcing.⁸

Scope 1. Direct emissions due to inhalation anaesthetics.

Inhalation anaesthetics have been used since the first ether narcosis by William Morton in 1846 to induce general anaesthesia for operations. These drugs are potent GHGs that are virtually not metabolised by the body and are vented unchanged via exhaled air into the atmosphere after surgery, where they remain until broken down. Nitrous oxide, for example, remains in the atmosphere for 114 years before decomposition and is a 298 times stronger GHG than CO_2 . The modern volatile inhalation anaesthetic desflurane is even 2,540 times stronger as a GHG than CO_2 and can account for more than 50% of the carbon footprint of OR complexes when used as standard practice by anaesthesiologists.¹¹

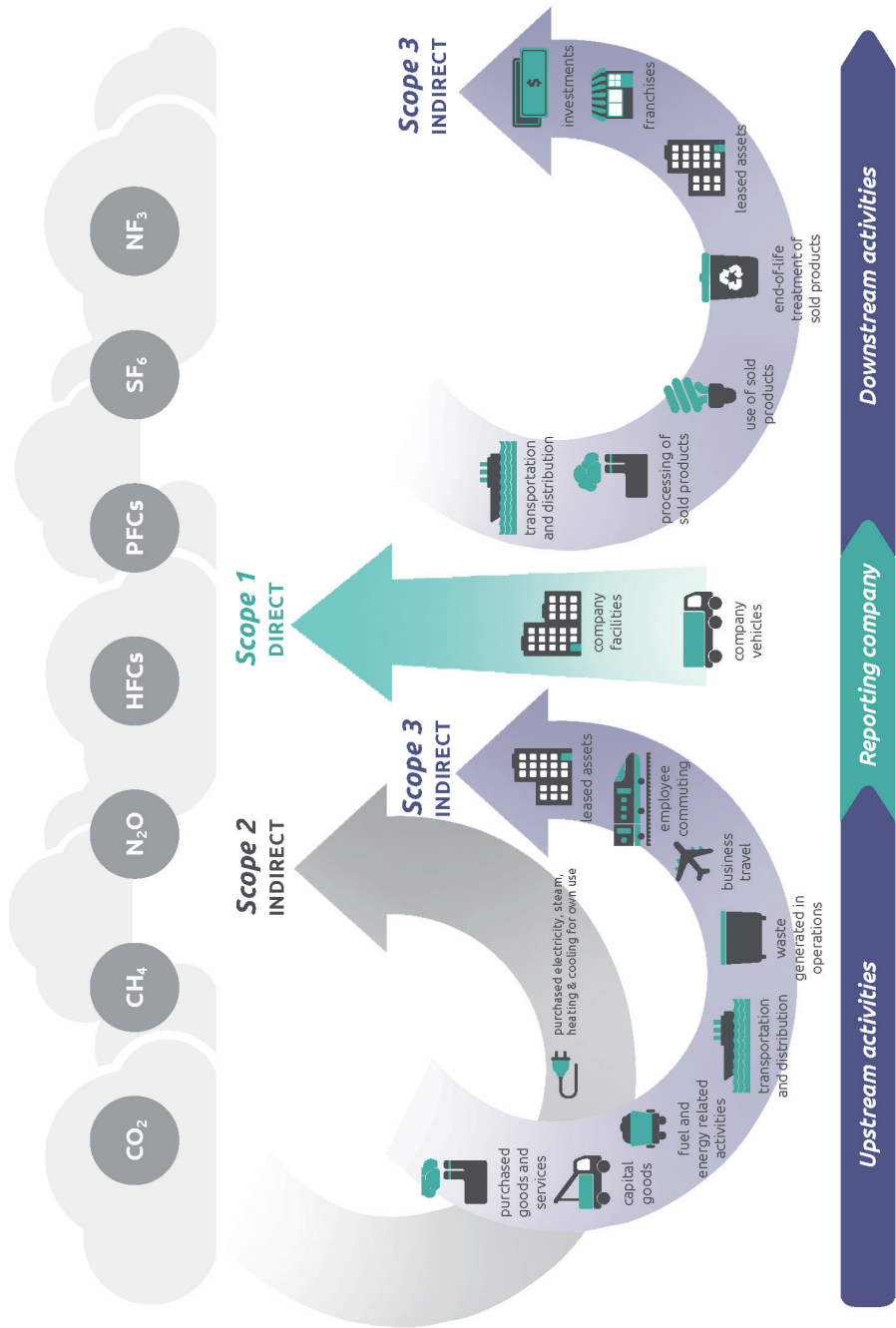


Figure 3. Overview of GHG Protocol scopes and emissions across the value chain.¹⁰

Scope 2: Indirect emissions due to energy consumption by the heating, ventilation, and air conditioning (HVAC).

To prevent airborne contamination of the wound, ORs are equipped with HVAC systems. Frequent and high-quality air filtering reduces the concentration of airborne pathogens from the skin and nasopharynx of those present in the room, thus reducing the chance of airborne contamination of the wound. To ensure good air quality, in practice 20-25 air changes per hour are necessary. It therefore takes a great deal of energy to keep the temperature, humidity and ambient pressure constant. Due to these high demands placed on the air quality inside the OR, 90-99% of the OR complex's energy consumption is due to air treatment.¹¹

Scope 3: Indirect emissions due to procurement of goods and waste generation.

A vast array of supplies is often required to perform operations. These include personal protective equipment, surgical instruments, wound care products, anaesthesia supplies, surgical drapes and towels, and so on. The majority of surgical supplies are currently intended for single use, based on the notion that disposable items are 'safer', more economical, and more convenient to use. Compared to reusable items, disposable items require a considerable quantity of raw materials, and their production, packaging, transport, and disposal generate large amounts of concealed CO₂ emissions, which accumulate throughout the life cycle of the product. Furthermore, the use of these disposables is also responsible for the large volume of waste generated during operations. In a study of three large Western hospitals, the waste from 70,000 operations was measured and averaged 14.5 kg per operation.¹¹

Additionally, but not within the boundaries of this thesis, a part of Scope 3 encompasses emissions resulting from staff, patient, and business travel. A carbon footprint assessment of the National Health Service (NHS) in England estimated this to be 13.5% of all healthcare emissions in 2019.¹²

Aim and outline of this thesis

The aim of this thesis is to investigate how the carbon footprint of ORs can be reduced in order to mitigate the impact of healthcare on the environment, without compromising patient safety. To this end, we will focus on those areas that have a major impact on the carbon footprint of an OR, so-called 'low-hanging fruit'. By addressing these potential quick wins, we aim to contribute to the Green Deal's goal of reducing healthcare-related CO₂ emissions by 55% by 2030.



In Part I, the reduction of major determinants of Scopes 1, 2, and 3 of the OR is investigated: inhalation anaesthetic use, energy consumption due to air treatment and waste generation resulting from widely used sterilisation packaging material for surgical instruments. In addition, the possibility of reducing the carbon footprint of heart valve replacement, a major operation that consumes a significant number of resources, is being investigated.

In Part II, two mitigation tools are developed to quantify carbon emissions and identify hotspots, so that carbon emissions can be reduced efficiently. The first tool works at the micro level (specific operations) and the other at the macro level (OR complexes on a national scale).

Finally, we will discuss the results of Parts I and II of this thesis and twelve practical implications derived therefrom, based on the 10R Framework, a model for transitioning from a linear to a circular economy based on hierarchical measures (Figure 4).¹³ Lastly, we will consider what future steps need to be taken to ultimately move towards a net-zero carbon emission OR by 2050.

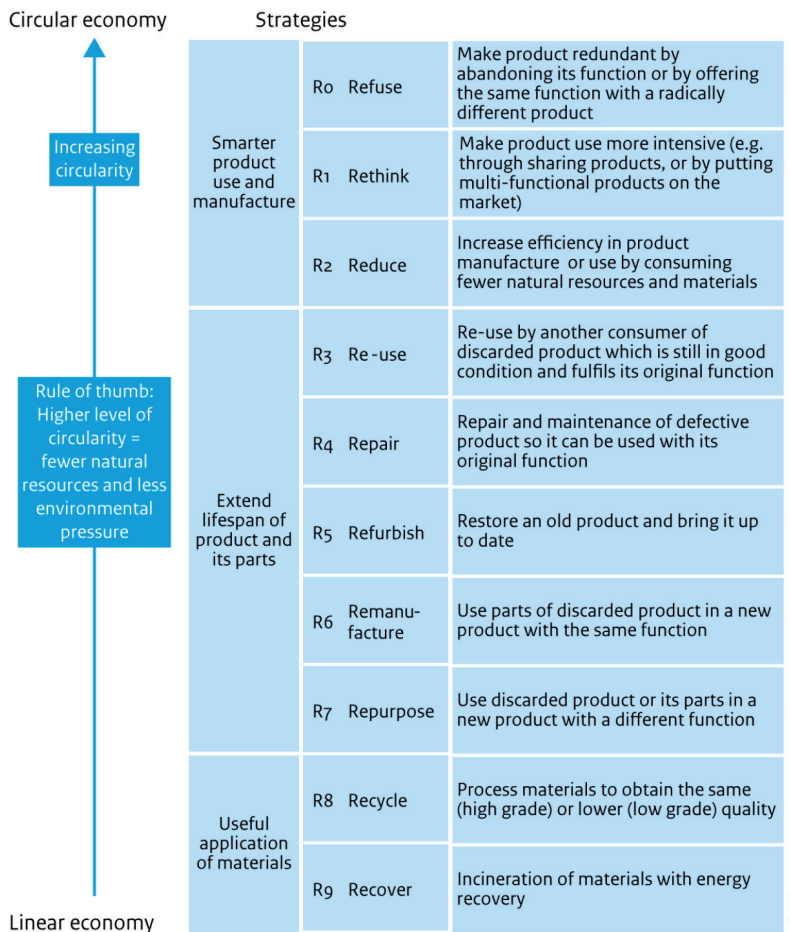


Figure 4. 10R Framework to increase circularity. ¹⁴

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