Toward a Net-Zero Health Care System: Actions to Reduce Greenhouse Gas Emissions

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COMMENTARY

Toward a Net-Zero Health Care System: Actions to Reduce Greenhouse Gas Emissions

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Health care accounted for 4.6% of global greenhouse gas (GHG) emissions in 2017. If global health care services were a country, they would represent the fifth-largest source of GHG emissions. Health care emissions stem directly from the operations of health care facilities (defined as scope 1 emissions) as well as indirectly from purchased sources of energy (scope 2) and the supply chain of health care services and goods (scope 3). In this article, the authors briefly review sources of GHG emissions in health care and explore opportunities for mitigation that can help to move toward an environmentally sustainable, net-zero health care system. The authors focus on mechanisms to reduce scope 1 and scope 2 emissions along with scope 3 emissions that can be significantly influenced by health care systems. They categorize interventions across five categories: buildings, transport, food, pharmaceuticals, and waste. As a sixth category, they detail the role that physicians can play in mitigating emissions from health care and society in general. The authors also describe co-benefits of these interventions along with potential barriers to adoption. Operationalizing these changes will require actions at individual, institutional, and regional/federal levels, employing a sustainability lens in each decision that impacts the delivery of health care.

The world has already warmed by at least 1.1°C compared with preindustrial levels, resulting in worsening planetary and human health, and is moving closer to the agreed limit of maintaining temperatures “well below 2°C.”[1] Climate change has resulted in increased frequency of heat waves, heavy precipitation, droughts, and tropical cyclones.[2] At the same time, combating climate change may be “the greatest global health opportunity of the 21st century.”[3] Realizing this opportunity will entail reducing greenhouse gas (GHG) emissions related to health care, which accounted for 4.6% of global GHG emissions in 2017.[3] In fact, if the world’s health services were a country, they would represent the fifth-largest source of GHG emissions on the planet.[4]

In this article, we detail sources of GHG emissions in health care and explore opportunities for mitigation that can help to move toward an environmentally sustainable, net-zero health care system. Additionally, we describe barriers to widespread implementation of these solutions. We performed a targeted review of the scientific and gray literature to identify sources that illustrate key issues within each sector considered.

Search Strategy and Selection Criteria

In the present article, we do not aim to provide a systematic literature review with quantitative synthesis of results, but rather a critical synthesis and detailed viewpoint of issues and actions related to moving to a net-zero health care system.

The review is primarily based on the the Working Group III (WG III) contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), which assessed the literature on the scientific, technological, environmental, economic, and social aspects of mitigation of climate change.[5] Findings from that report were adapted to health care systems and supplemented through searches of Google Scholar, the reference lists of relevant peer-reviewed and non-peer-reviewed articles, and books. Only articles and books published in the English language were included. Major sources of information and ideas included Project Drawdown, Delivering a Net Zero National Health Service, the Canadian Coalition for Green Health Care, and Health Care Without Harm.

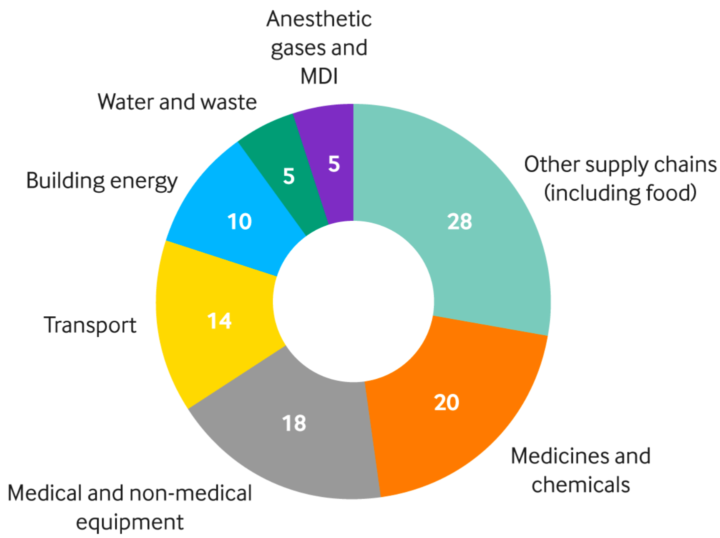
> “ *If the world’s health services were a country, they would represent the fifth-largest source of GHG emissions on the planet."*

Sources of Carbon Emissions, with Opportunities for Mitigation

Health care emissions stem directly from the operations of health care facilities (scope 1) as well as indirectly from purchased sources of energy (scope 2) and the supply chain of health care services and goods (scope 3).[6] The United States is responsible for the highest absolute health care emissions (27% of global burden of health care emissions), followed by China (17%), despite China having surpassed the U.S. in overall absolute greenhouse gas emissions in 2006. In terms of per capita health care emissions, top emitters include Canada, the U.S., Australia, and Switzerland.[7]

Figure 1 describes the various sources of carbon emissions in the United Kingdom (U.K.) National Health Services (NHS) from all three scopes. In 2020, the NHS set a target of net-zero emissions from scope 1 and scope 2 emissions by 2040, with a second goal of net-zero emissions from all three scopes by 2045. Following the U.K., 13 countries announced at the 2021 United Nations Climate Change Conference (COP26) in Glasgow that they will now aim for net-zero health care systems on or before 2050.[8]

FIGURE 1
GHG Contribution
Pie chart showing sources of carbon emission in the UK NHS, including all three emission scopes. (%)



Source: Created with data from: Delivering a Net Zero NHS, https://www.england.nhs.uk/greenernhs/a-net-zero-nhs/.
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This article will focus on mechanisms to reduce scope 1 and scope 2 emissions along with scope 3 emissions that can be significantly influenced by health care systems. We describe interventions in five categories — buildings, transport, food, pharmaceuticals, and waste. As a sixth category, we detail the role that physicians can play in mitigating emissions from health care and society in general.

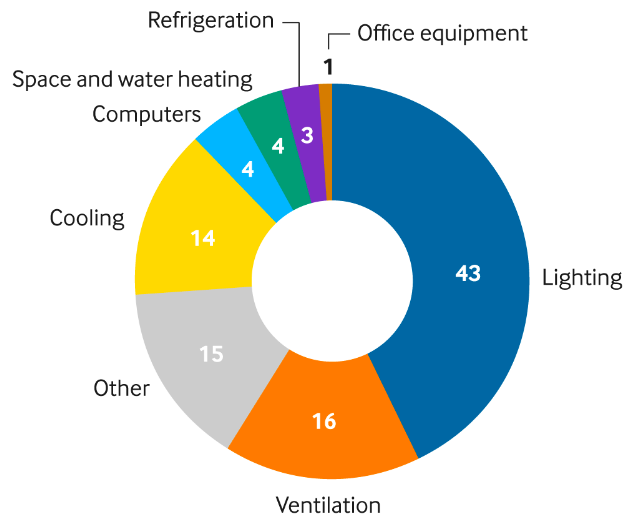
Hospital Buildings

Buildings account for 31% of global energy demand and 21% of global GHG emissions.[5] Hospitals, particularly large hospitals, are on average more energy-intensive than other commercial buildings, highlighting the significant potential to reduce GHG emissions from hospital buildings. For instance, in the U.S., large hospitals (>200,000 square feet) consume 5.5% of the total delivered energy used by the commercial sector while representing a smaller fraction of total commercial floor space. Many hospitals globally use fossil fuels directly (coal, natural gas, and oil), primarily for space heating, water heating, and cooking, thus contributing significantly to scope 1 emissions.[9] In addition, electricity consumption is a major source of emissions for hospital buildings (scope 2 emissions). Figure 2 depicts various contributors of electricity consumption in U.S. hospitals, with lighting, cooling, and ventilation accounting for nearly three-quarters of this consumption.

FIGURE 2

Health Care Electricity Consumption

Pie chart depicting major contributors to health care electricity consumption in the U.S. (%)



Source: Created with data from: US Energy Information Administration (EIA).

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Actions to decrease GHG emissions from hospital buildings are summarized in Table 1, categorized by electrification, energy efficiency, and renewable electricity generation. Electrification of all energy use in buildings, particularly direct use of fossil fuels for heating and cooking, is vital to decreasing the carbon footprint of hospital buildings. A range of energy-efficiency measures can be implemented to decrease the energy consumption of health care facilities. Finally, on-site renewable electricity generation or purchase agreements (wind or solar) are viable solutions for many health care facilities, with multiple examples (and co-benefits) of such facilities.

Low-emission and net-zero buildings also can help health care systems adapt to climate change by increasing resilience and decreasing operating costs. All new hospital buildings and campus redevelopment projects should have sustainability as a core principle, aiming for net-zero buildings. Importantly, hospitals can lead their communities[10] in adopting new norms around energy use, including showing leadership in the phase-out of fossil fuels.

Transport

In 2019, the transport sector accounted for 15% of total GHG emissions globally. Seventy percent of transport emissions came from road vehicles, while 12%, 11%, and 1% came from aviation, shipping, and rail, respectively.[5] Approximately 3.5% (9.5 billion miles) of all road travel in England relates to patients, visitors, staff, and suppliers to the NHS, accounting for 14% of the health system's total emissions (including 5% for patient travel, 4% for staff commutes, 4% for business travel and fleet transport, and 1% for visitor travel).

Table 1. Opportunities for Mitigation of Greenhouse Gas Emissions by the Buildings Sector

	Action	Co-Benefits	Barriers
Electrification	Using heat pumps for space and water heating, eliminating fossil fuel–based heating systems	Increased energy efficiency, lower energy costs, eliminate chances of gas-related hazards and fires	Initial cost of shift (for existing buildings), existing norms, need for supplemental space heating source if temperature goes below –25°C (–13°F)
	Use of non-fossil fuel–based district heating systems (distributing heat generated in a central location through insulated pipes) for space and water heating	Increased energy efficiency	High initial capital expenditure, requires multiple buildings in close proximity to be feasible
	Electrification of cooking	Increased energy efficiency, improved indoor air quality, decreased need for indoor cooling (induction cooking), lower energy costs, decrease kitchen hazards and fires	Initial cost of shift (for existing buildings), existing norms
Energy Efficiency	Install motion-sensor light switches to decrease waste of electricity for lighting	Decreased energy costs	Upfront retrofitting costs
	Improved insulation, use of high-performance glass *Example (insulation): Hamilton Health Sciences, Canada*[T1]	Decreased heating costs	Upfront retrofitting costs
	Use of non–air conditioning (AC)/heat pump–based cooling solutions such as fans, ventilation, white roofs, and/or green roofs *Example (green roofs): multiple hospitals*[T2]	Decreased electricity costs for cooling; rooftop gardens can also produce food, promote biodiversity, and are a green space for patients and staff	Culture of equating cooling with AC use
	Use of LED lights in place of incandescent or fluorescent lighting	Increased energy efficiency, decreased electricity costs, longer lifetime of light fixtures	Upfront costs
	Use of smart thermostats	Decreased energy costs	Upfront costs
	Building automation systems	Up to 40% lower energy costs	Upfront costs, technical complexity
Renewable Electricity Generation	Install solar panels *Example: Johns Hopkins University*[T3]	Increased resilience to grid breakdown, less energy dependence, lower energy bills	Space requirements
	Install a wind turbine on site		Space requirements, not suitable for all geographies
Other	Aiming for net-zero building design in all new buildings	Avoid future retrofitting costs	Potentially higher upfront costs for some design features

T1. Hamilton Health Sciences Environmental Performance Report 2021. Hamilton Health Sciences. Accessed October 1, 2022. https://www.hamiltonhealthsciences.ca/wp-content/uploads/2021/06/HHS-Environmental-Performance-Report-2021.pdf. T2. Pouya S, Demirel Ö. Hospital Rooftop Garden. Andalou University. DergiPark Akademik. Accessed October 1, 2022. https://dergipark.org.tr/tr/download/article-file/712900. T3. Solar Facility Now Supplying Renewable Energy for Two-Thirds of University's Electricity Use. Johns Hopkins University Hub. August 2, 2022. Accessed October 1, 2022. https://hub.jhu.edu/2022/08/03/skipjack-solar-center-now-operating. Source: The authors

> *"Reduced meat and dairy consumption, along with reducing food waste, are two key demand-side measures to reduce GHG emissions from the food system."*

Health care workers, particularly physicians, often have a hypermobile lifestyle that contributes disproportionately to this burden. For instance, travel associated with physical attendance at a single large academic conference can release as much CO_2 as an entire city does in a week.[11] Table 2 summarizes measures to reduce GHG emissions from transport in health care systems and outlines measures applicable to patients as well as health care workers.[12]

Table 2. Opportunities for Mitigation of Greenhouse Gas Emissions by the Transport Sector

	Action	Co-Benefits	Barriers
Patients	Telemedicine: enable increased access to virtual health care delivery through appropriate payment models and infrastructure provision	Increased access and convenience for patients, lower costs	Payment models that disincentivize virtual care
	Minimize use of air ambulance services to situations with clear evidence of clinical benefit	Decreased air ambulance crashes and deaths	Financial incentives favoring for-profit air ambulance services in certain countries (such as the U.S.)
	Electric vehicles: shift to energy efficient battery electric ambulances and other fleet vehicles	Lower air and noise pollution	Current ambulance technology, cost of vehicles
Health Care Workers	Fewer flights: shift to virtual academic conferences (biennially in person, combining conferences in a specialty [for instance, cardiology], lower fees for virtual attendance)	Lower costs, increased attendance, and diversity of attendees, less disruptive to personal life	Potentially lower networking opportunities and social interactions
	Living close to work: training programs can coordinate with local residential buildings to make it easier for trainees to live close to their workplace (e.g., discounts, providing information pre-orientation)	Cost savings for trainees, improved work-life balance, multiple health benefits of living close to work (shorter commutes)	Availability and affordability of residential buildings in close proximity
	Public transport: provide last-mile connectivity (such as through shuttles) to enable health care workers to use public transport	Lower costs, increased comfort	Availability of wider public transport infrastructure
	Parking: prioritize infrastructure for bikes (including showers and lockers) and electric vehicles	Improved health of workers using active transport	Initial cost (can use parking revenue from internal combustion engine vehicles for infrastructure upgrades)
	Carpooling: health care facilities can enable carpooling by providing supportive infrastructure (internal promotions, mobile applications, discounted or premium parking spots)	Reduced fuel and parking costs, reduced stress of driving, increased social interactions	Potential increase in commute time, current habits
	Virtual interviews: for graduate and postgraduate training programs such as residencies	Lower costs for applicants, reduced travel barriers for applicants with disabilities	Current practices, perceived advantages of in-person interviews
	Virtual learning: prioritize virtual leaning models, reserving in-person learning for where a clear advantage exists (for instance, skills demonstration)	Greater flexibility for trainees, increased opportunities for work-life balance	Current beliefs and practices, need for a culture shift

Source: The authors

Food

Unhealthy and unsustainably produced food is a major risk to both people and the planet.[13] Reduced meat and dairy consumption, along with reducing food waste, are two key demand-side measures to reduce GHG emissions from the food system.[5] In addition to GHG emissions, meat and dairy production are major drivers of deforestation, loss of biodiversity, and freshwater use.[14] Co-benefits of moving to plant-based foods include lower risk of cardiovascular disease, type-2 diabetes, cancer, and all-cause mortality, along with reduced malnutrition (undernutrition and obesity) in developing countries.[15] Health care systems continue to emphasize meat in their meals, despite decades of evidence of its human health risks, including the classification of processed meat and red meat as carcinogens by the International Agency for Research on Cancer. Similar to the movement to phase out tobacco from health care settings, there is an urgent need to phase out unsustainable meat and dairy[16] consumption in health care settings.

Table 3. Opportunities for Mitigation of Greenhouse Gas Emissions by the Food Sector

	Action	Co-Benefits	Barriers
Decreasing Meat and Dairy Consumption	Meatless Mondays[T1] *Example: New York City*[T2]	Improved health outcomes, can serve as a healthy eating teaching opportunity for patients	Current food habits, traditions, and beliefs
	Change "default" menu to plant-based foods		
	Phase out red meat from all menus		
	Consult with plant-based chefs to create tasty and healthy plant-based menus	Increased patient satisfaction	Associated costs
Decreasing Food Waste *Examples: CH Niort, France*[T3]*and Illinois, U.S.*[T4]	Monitor and measure food waste, using the information to remove unpopular items and other sources of waste	Cost savings	Requires leadership to coordinate multiple stakeholders, institutional commitment
	Training food handlers on interpreting various packaging dates to avoid wasting safe-to-eat foods	Cost savings	Food preparation is often outsourced
	Improve communication between the kitchen and patient units (option to cancel meals, offer different portion sizes, other patient preferences)	Improved patient satisfaction and nutrition	May require more labor input, potentially increased costs
	Allow patients to order and customize meals, when feasible (including preorders and electronic ordering)		
	Redistribute surplus food to food banks or other charitable schemes	Decreases food insecurity in community	Requires close engagement with external stakeholders
Other	Compost and/or bio-digestion of food waste	Can generate energy and/or fertilizer	Lack of municipal facilities, initial cost of setting up facilities on-site
	Use select food waste items as animal feed	Decreases input costs in animal agriculture	Availability of animal farms close by, engagement with external stakeholders
	Source food locally where possible, minimize foods transported over long distances	Increased freshness of food	Lack of availability of certain foods in close vicinity

T1. Meatless Monday. Monday Campaigns. GRACE Communications Foundation. Accessed October 1, 2022. https://www.mondaycampaigns.org/meatless-Monday. T2. Gottfried M. America's Largest Municipal Hospital System Now Offers Meatless Mondays. Forks Over Knives. January 3, 2022. January 3, 2022. Accessed October 1, 2022. https://www.forksoverknives.com/wellness/nyc-health-hospitals-meatless-mondays/. T3. Food for Healthcare: MECAHF Project. Health Care Without Harm. Accessed October 1, 2022. https://foodforhealthcare.org/mecahf-project/. T4. Reducing Wasted Food in Illinois Hospitals & Healthcare Systems. Alliance for Health Equity. April 6, 2022. Accessed October 1, 2022. https://wastedfoodaction.org/wp-content/uploads/2022/04/Reducing-Wasted-Food-in-Illinois-Hospitals-slides.pdf. Source: The authors

Health care systems produce a significant amount of food waste. In large Canadian hospitals, close to 50% of food placed at a patient's bedside is wasted, with a single hospital sometimes generating 1 ton of food waste a day.[17] As the costs associated with food waste are externalized (in the form of environmental and municipal costs), health care systems have little incentive to make reducing food waste a priority. Increased regulation, monitoring requirements, and schemes to price food waste can help health care systems to prioritize reducing food waste. Other measures to reduce GHG emissions from food in health care systems are outlined in Table 3.

Pharmaceuticals

Aggregate global emissions from the pharmaceutical industry exceed the emissions from the global automotive industry but receive far less attention.[18] Prescription drugs account for ~10% of the U.S. health care system's emissions (scope 1 and 2 emissions).[19] In the U.K. NHS, across all three scopes, medicines and chemicals account for up to a quarter of GHG emissions. While a substantial portion of pharmaceutical emissions are in scope 3 and will require actions from the pharmaceutical industry for adequate mitigation, there are two areas in which health care providers can significantly reduce emissions: anesthetic gases and metered-dose inhalers (MDIs). Opportunities for mitigation of GHG emissions from pharmaceuticals are summarized in Table 4.

Anesthetic Gases

Anesthetic gases used in surgery, such as halothane, nitrous oxide, isoflurane, sevoflurane, and desflurane are potent GHGs. With <5% of the total delivered halogenated anesthetic being metabolized by the patient, most of the anesthetic is routinely vented to the atmosphere.[20] Desflurane has a particularly high carbon footprint, with emissions from one bottle being equivalent to burning 440 kg of coal. Twenty-year global warming potential (GWP_{20}) values for the inhaled anesthetics are 3,714 for desflurane, 1,401 for isoflurane, and 349 for sevoflurane.[21] To illustrate the impact of these gases in more familiar terms, the use of an anesthetic machine for 1 hour of desflurane anesthesia is equivalent to driving 370 km in a car, compared with 50 km for 1 hour of sevoflurane use.

> “*A phacoemulsification cataract surgery (one of the most common surgeries globally) in a U.K. hospital produces 20 times the GHG emissions of the same procedure in an Indian hospital, with similar outcomes and safety profiles."*

Inhaled anesthetics are often delivered with N_2O as a carrier gas (usually because of its analgesic effects). However, N_2O has an atmospheric lifetime of 114 years, while the atmospheric lifetime of the longest-lived inhaled anesthetic (desflurane) is 10 years. Given this difference, the impact of N_2O needs to be considered over a 100-year period (GWP_{100}).[20] Therefore, an alternative to N_2O should always be sought whenever possible.[22] A comparison of the carbon dioxide equivalent (CDE_{100}) values of commonly used anesthetic gases, with and without N_2O, is shown in Figure 3.[21] Instituting department-level policies that incorporate measures outlined in Table 4 can be effective for decreasing the GHG impact of anesthetic gases.[23]

Table 4. Opportunities for Mitigation of Greenhouse Gas Emissions from Pharmaceuticals

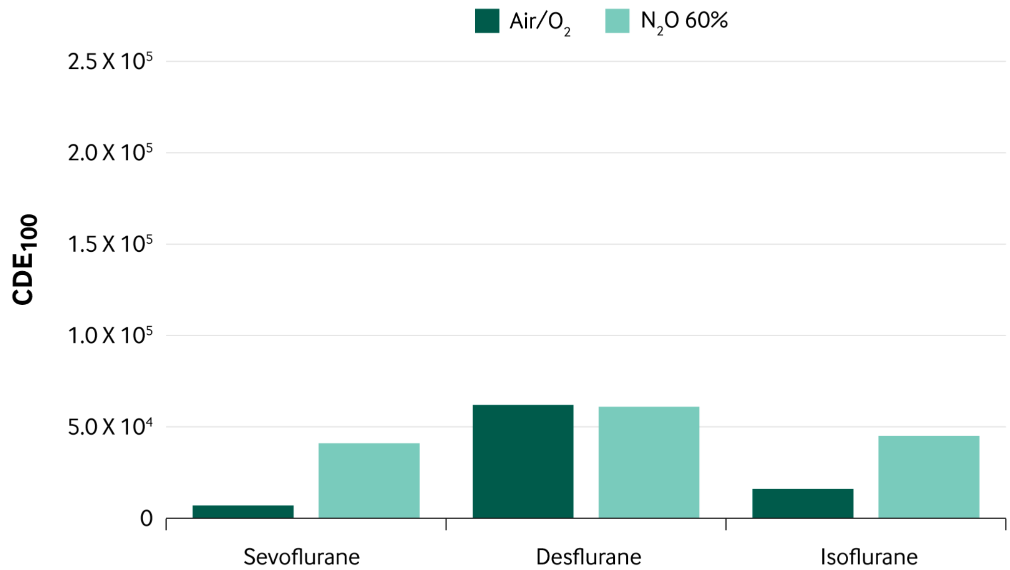
	Action	Co-Benefits	Barriers
Metered-Dose Inhalers	Switching from MDIs to DPIs	Breath-actuated (no coordination needed)	Requires a deep breath, making it unsuitable for small children, the frail elderly, and those unable to mount a strong inspiratory effort; increased costs
	Switching from MDIs to SMIs	Easy to use correctly, often preferred by patients over MDIs	Not available in many countries and for many pharmaceutical agents; increased costs
	Making DPIs and SMI the preferred formulary agent in hospitals and other health care settings over MDIs, where clinically feasible	Normalizes environmental considerations in health care decision-making	Lack of regulatory pressures, environmental harms not usually considered in decision-making, ability to externalize environmental costs
	Incorporation of environmental harms of health care while framing clinical guidelines for COPD and asthma	Normalizes environmental considerations in health care decision-making	Requires a shift in clinical guideline frameworks, status quo
	Allow hospitalized patients to keep their partially used inhalers upon discharge	Decreased biomedical waste generation, decreased costs	Current hospital policies in some places that encourage disposal of partially used inhalers at time of patient discharge
Anesthetics *Example: American Society of Anesthesiologists*[T2]	Minimize use of desflurane *Example: Ohio State University, U.S.*[T1]	Minimize chronic exposure to health care workers, decreased costs	It plays a role in rapid extubation and recovery, especially in centers without a recovery unit and in centers with high patient volumes
	Minimize use of N_2O as a delivery gas; decommission/avoid installing N_2O centralized piping, and substitute portable tanks that remain closed between use	Minimize chronic exposure to health care workers, avoid side effects of N_2O	Need for additional analgesia in the absence of N_2O
	Capture and reuse or destruction of N_2O	Decreased operating costs due to less volume of N_2O consumed	Initial costs, access to technology
	Avoiding high gas-flow rates where possible	Reduced inhaled anesthetic use, decreased costs, decreased adverse effects from high exposure	High flow rates have a role in both induction and emergence from anesthesia, low consideration of environmental impact in routine anesthesia practice
	Use of scavenging systems	Decreased exposure of health care workers to inhalation agents, decreased operating costs due to decreased consumption of anesthetics	Initial costs
	Using regional or intravenous anesthesia where clinically feasible	Improved side-effect profile, decreased occupational exposure of inhaled anesthetics	Use limited to specific settings, inhalation agents more effective in certain scenarios
	Using xenon as an inhalation anesthetic	Rapid induction and emergence, analgesic and hypnotic effects with minimal hemodynamic effects, increased safety for health care workers	High costs
	Checking anesthetic machine before each use, using a fitted face mask, adequate inflation of endotracheal tube/laryngeal mask cuff	Reduced inhaled anesthetic use and associated costs, reduced health care worker exposure	Decreasing environmental costs low priority in decision-making, current practice

MDI = metered-dose inhaler, DPI = dry-powder inhaler, SMI = soft-mist inhaler, COPD = chronic obstructive pulmonary disease. T1. Sustainability at the Ohio State University Wexner Medical Center 2020–2021. Ohio State University. Accessed October 1, 2022. https://wexnermedical.osu.edu/-/media/files/wexnermedical/about-us/sustainability/corp_21301123_sustainabilityaccomplishmentsreportrevextaud_v1.pdf. T2. Inhaled Anesthetic 2022 Challenge. American Society of Anesthesiologists. Accessed October 1, 2022. https://www.asahq.org/about-asa/governance-and-committees/asa-committees/environmental-sustainability/inhaled-anesthetic-challenge. Source: The authors

FIGURE 3

GHG Emissions from Inhaled Anaesthetics

One hour of inhaled anaesthetic, delivered with air/oxygen (O2) or 60% nitrous oxide (N2O), adjusted to deliver 1 MAC-hour anaesthetic at 2L fresh gas flow.



CDE_{100} = 100-year carbon dioxide equivalent (in grams). MAC = Minimum Alveolar Concentration.
Source: Created with data from: Ryan, Susan M., and Claus J. Nielsen. Global warming potential of inhaled anesthetics: application to clinical use. Anesth Analg. 2010 Jul;111(1):92-8. doi: 10.1213/ANE.0b013e3181e058d7. Epub 2010 Jun 2.
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Metered-Dose Inhalers

Inhalers are used by individuals with a variety of respiratory conditions, ranging from asthma to chronic obstructive pulmonary disease (COPD). Most of the emissions come from the propellant in MDIs, rather than the medicine itself. The primary alternative to MDIs are dry-powder inhalers (DPIs) and soft-mist inhalers (SMIs). According to the U.K. NHS, the switch to lower-carbon inhalers (such as DPIs) by just 30% of users would result in a reduction of 374 kt CO_2e per year. Table 5 shows that if England adopted the same low rate of MDI use as Sweden, 550 kt CO_2e would be saved annually.[24] Notably, despite the difference in use of MDIs, clinical outcomes for patients with asthma are similar in the U.K. and Sweden, suggesting that a shift away from MDIs is safe for patients.[25]

Waste

Waste in health care is widespread and involves multiple dimensions. While material waste (such as plastic, water, and paper) is most concrete, waste resulting from provision of low-value health care and other systemic deficiencies likely has a larger environmental impact.[26] In addition, how people die has radically changed over the last few generations. Dying is now often prolonged and medicalized, while the role of the family and community has receded. In high-income countries,

Table 5. Potential Reduction in GHG Emissions if MDI Use in England Was Similar to That in Sweden*

Inhaler Class	England % MDI	Sweden % MDI	England CO_2e (kt) per year	England Potential Annual Reduction of CO_2e (kt)
SABA	94	10	414	350
LABA	65	2	9.3	8.4
SAMA	100	100	8.4	0
ICS	94	15	127	101
ICS+LABA	47	13	140	91

GHG = greenhouse gas, MDI = metered-dose inhaler, SABA = short-acting beta agonist, LABA = long-acting beta agonist, SAMA = short-acting muscarinic antagonist, ICS = inhaled corticosteroid. *Analysis uses 2017 community prescribing data from the NHS in England (https://digital.nhs.uk/) and assumes that the carbon footprint of MDI is 20 kg CO_2e and that of DPI is 1 kg CO_2e. SAMA is not included in the analysis as no DPI SAMA alternative is available. The values in the Potential Annual Reduction column show the hypothetical carbon savings if England were to prescribe the same proportions of MDI as Sweden. Source: Created with data from: Janson C, Henderson R, Löfdahl M, Hedberg M, Sharma R, Wilkinson AJK. Carbon footprint impact of the choice of inhalers for asthma and COPD. Thorax 2020;75:82–84. https://pubmed.ncbi.nlm.nih.gov/31699805/. 10.1136/thoraxjnl-2019-213744.

~10% of annual health expenditures for the entire population is spent on the <1% of people who die that year. Climate change, disregard for environmental costs, and our wish to defeat death have a common origin in the (misguided) belief that we are in control of, not part of, nature.[27] As outlined by the Lancet Commission on the Value of Death, we as a society need to understand death as a relational and spiritual event, rather than a purely physiological process. Recognizing the value of death will help to reorient health care systems away from futile or inappropriate treatments at the end of life, which will decrease suffering and waste, enhance the role of the family and wider community, and increase the environmental sustainability of the health care system.

Material Waste

There are large variations between countries in GHG emission for similar medical procedures. For instance, a phacoemulsification cataract surgery (one of the most common surgeries globally) in a U.K. hospital produces 20 times the GHG emissions of the same procedure in an Indian hospital, with similar outcomes and safety profiles.[28] The procurement of single-use or disposable supplies (including their supply chain emissions) accounts for the largest part of this difference.[29] Plastic waste alone can represent approximately 25% of the waste generated in hospitals. Excessive infection-control standards that are not grounded in evidence, particularly in the Global North, are a major source of waste. A common infection-control viewpoint assumes that there is no limit to the cost or materials required to avoid any risk of health care–acquired infection. Regulations arising from such values are largely based on theoretical risks to individuals and discount the opportunity costs of overpaying. Ultimately, this leads to the failure to evaluate the cost-utility of proposed policies and the production of potentially unnecessary waste.[30]

> “ *Given their relative affluence in society, physicians themselves are an important source of GHG emissions."*

An average of 570 gallons of water is used per staffed hospital bed per day in the United States. In contrast, the average U.S. citizen reportedly uses an estimated 150 gallons of water per day, while the average African citizen uses 5 gallons of water per day. Domestic or restroom use makes up the largest fraction of hospital water use[31] (35% in the U.S.), followed by cooling and heating systems (20% in the U.S.), creating opportunities for reducing water waste in these areas.

The Covid-19 pandemic has led to further increases in health care waste, exacerbating the environmental impacts of solid waste. The World Health Organization (WHO) outlined several recommendations in this regard, including developing and using safely reusable personal protective equipment (PPE) while reducing unnecessary PPE use through safe and rational use. In addition, reduced packaging volumes and increased investment in environmentally sustainable PPE and waste systems[32] are needed. Table 6 summarizes further opportunities for mitigation of GHG emissions by decreasing waste across multiple dimensions.[33]

Physicians as Role Models for Society

Health care workers have performed a pivotal role in the fight against nuclear weapons and tobacco by spreading authoritative information and changing social norms. In the last few years, increased awareness of the health effects of climate change has been an important force for climate action.

On the other hand, given their relative affluence in society, physicians themselves are an important source of GHG emissions. Globally, households with income in the top 10% contribute about 36–45% of global GHG emissions. About two-thirds of the top 10% of physicians live in developed countries, and one-third live in other economies.[34] In many countries, a large proportion of physicians likely belong to households with income in the top 10%. Therefore, by reducing their GHG emissions, physicians can model a low GHG emissions pathway for the wealthy and create new social norms in this regard. It has been shown that between 10% and 30% of committed individuals are required to set new social norms.[35] In fact, hospitals were one of the first places in society where norms around tobacco use changed, when many physicians quit tobacco as the data around tobacco and health crystallized. Table 7 summarizes opportunities for GHG mitigation by physicians and other health care workers, including their co-benefits and barriers to adoption.

> *“Targeted funding measures are needed for health care–specific GHG emissions (anesthetics, MDIs, health care regulations, health care waste). As countries commit to moving toward net-zero health care systems, there need to be regulations and funding that follow such commitments, which target GHG emissions from health care."*

Strategies to Overcome Barriers to Adoption

Measures can be employed at governmental (federal/regional), institutional, departmental, and individual levels to overcome barriers to adoption, with decreasing effect size at lower socioecological levels. Given that a major barrier across interventions is cost-related, funding through governments likely will have a large effect on overcoming barriers to many of the proposed interventions. While major climate legislation (such as the recently passed Inflation Reduction Act in the U.S. or carbon pricing schemes in Canada and the European Union) can help to decrease cost-related barriers, more targeted funding measures are needed for health care–specific GHG emissions (anesthetics, MDIs, health care regulations, health care waste). As countries commit to

Table 6. Opportunities for Mitigation of Greenhouse Gas Emissions by Decreasing Waste

	Action	Co-Benefits	Barriers
Plastic Waste	Use washable linen (such as sterile gowns, adult diapers), in place of single-use plastic-based materials	Potentially lower costs	Requires infrastructure to wash and sterilize
	Use washable utensils in eating spaces, with multiple receptacles to collect used utensils, in place of single-use materials	Lower microplastic contamination of foods	Requires infrastructure and labor to wash and clean
	Install water fountains and stop the sale of single-use plastic beverage bottles	Improved health outcomes from stopping sales of sugar-sweetened beverages	Initial cost, culture shift
	Reuse hard plastics such as urinals, bedpans, water pitchers	Reduced environmental issues associated with plastic waste	Associated cleaning costs
	Switch to reusable glassware where feasible such as for lab tests	Reduced microplastic contamination	Current systems designed for single use (and throw), cultural emphasis on throughput rather than minimizing waste
Paper Waste	Install bidets in toilets in addition to the option of toilet paper	Reduced deforestation ("tree to toilet" pipeline), decreased virtual water use, cost savings with use of air-dryers	Existing social norms
	Air-dryers instead of paper-based drying		Initial cost of shift
Water Waste *Example: Providence St. Peter Hospital, Washington, U.S.*[T1]	Assess water use to identify opportunities for savings and track results	Operational cost savings	Cost of putting data collection system in place
	Installing dual-flush, low-flow flush systems	Operational cost savings	Initial cost of shift, need to teach correct usage
	Installing low-flow fixtures (showers and taps), in place of conventional fixtures	Energy savings (less hot water use)	Retrofitting costs
	Checking regularly for leaks, and when found, repairing them promptly	Operational cost savings	Labor costs
	Eliminate single-pass cooling in water-cooled equipment by recirculating cooling water or moving to air-cooled systems	Operational cost savings	Retrofitting costs
	Design water-smart landscapes (for instance, less lawn space) that have reduced water needs, while providing beautiful surroundings	Operational cost savings	Cultural preference for water-intensive lawns in many countries

	Action	Co-Benefits	Barriers
Other	Routine public reporting of waste generation, by category, in health care facilities	Can form a basis for identifying opportunities for improvement and measuring progress	Costs of data collection
	Recycling metals, paper, e-waste, and textiles	Decreased extraction of natural resources	Recycling infrastructure, limited historical success of some recycling programs and current incentives
	Emphasizing prevention over resource-intensive curative services	Improved health outcomes	Financial reimbursement structures often favor curative services and reward increased resource use
	Provision of end-of-life services, including palliative care, hospice services, and medical assistance in dying *Example: Kerala (India)*[T2]*and Canada*[T3]	Improved control at end of life, increased patient satisfaction	Strong culture of death-denial in many health care systems and societies
	Bodies that design regulations and policies (such as infection control) should incorporate environmental and waste implications of their recommendations	Decreases siloed decision-making, allows environmental factors to be incorporated in all decision-making	Culture of disregarding waste and environmental implications of recommendations and policies, lack of expertise
	Creating a circular economy for medical devices, emphasizing sterilization and reprocessing *Example: Aravind Eye Care, India*[T4]	Cost savings in the medium to long term, increased resilience to supply-chain failures	Capitalism, focus on containing short-term costs over maintaining long-term sustainability, ability to externalize environmental costs, certain regulations that favor single-use devices and disposability
	Routine inclusion of environmental outcomes in clinical trials, with opportunities for frugal innovation from the Global South to drive resource-efficient practice in the Global North	Creates a two-way learning environment between the Global North and Global South, allows environmental considerations to be incorporated in all health care decision-making	Increased data-collection burden, unconscious bias in Global North health care personnel about learning from the Global South
	Decreasing low-value health care services	Decreased embedded emissions in health care services (scopes 1–3), improved patient outcomes	Current financial incentives in many health care systems, culture, practice of defensive medicine

T1. Silvas J. Hospitals Can Tap into Savings Through Water Conservation. Healthcare Design. January 15, 2013. Accessed October 1, 2022. https://healthcaredesignmagazine.com/architecture/saving-water-saving-money/. T2. Sallnow L, Smith R, Ahmedzai SH, et al. Report of the Lancet Commission on the Value of Death: bringing death back into life. Lance Commissions 2022;399:837–884. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02314-X/fulltext. 10.1016/S0140-6736(21)02314-X. T3. Get the Facts: Canada's Medical Assistance in Dying (MAID) Law. Dying with Dignity Canada. Accessed October 1, 2022. https://www.dyingwithdignity.ca/end-of-life-support/get-the-facts-on-maid/. T4. Thiel CL, Schehlein E, Ravilla T, et al. Cataract surgery and environmental sustainability: waste and lifecycle assessment of phacoemulsification at a private healthcare facility. J Cataract Refract Surg 2017;43:1391–1398. https://www.sciencedirect.com/science/article/abs/pii/S0886335017307113. 10.1016/j.jcrs.2017.08.017. Source: The authors moving toward net-zero health care systems, there need to be regulations and funding that follow such commitments, which target GHG emissions from health care.[8]

At an institutional level, collecting data on emissions and making them publicly available can help to identify priorities for action. Standardization of data-collection frameworks in health care settings is needed to allow actionable inferences from the data and to prevent "greenwashing." Furthermore, for meaningful emission reductions, data-collection frameworks should be complemented by an institutional commitment to implement change. Given that carbon emissions are embedded in multiple decisions made by health care leadership, there is a need for a sustainability lens in all decision-making in health care. Health care leadership also can try to raise funds for the sustainability transition through philanthropic contributions, as is currently done for many capital projects in hospitals.

Similarly, individual departments should identify departmental priorities for action, starting with more frequent conversations within departments about their carbon emissions and possible solutions. Finally, individuals can be potent agents of change, in their personal lives as well as by advocating for structural change within their department, institution, government, and the global health care landscape.

Table 7. Opportunities for Mitigation of Greenhouse Gas Emissions by Physicians and Other Health Care Workers

	Action	Co-Benefits	Barriers
Transport	Live car-free: shift to public transport, walking, and cycling	Improved physical activity, lower expenses, improved mental health	Limited public transport infrastructure, suboptimal built environment
	Fewer flights: shift to virtual conferences and commuting by rail/bus (short distances)	Increased time with family, lower expenses	"Old habits die hard," decreased social interactions
	Electric vehicle: shift to energy efficient–battery electric cars and scooters	Decreased energy and maintenance costs	Initial cost of electric vehicles, availability, charging infrastructure
Buildings	Smaller homes: living in a smaller-sized home such as a condominium or apartment	More social interactions, fewer maintenance tasks, improved health (less urban sprawl)	Existing social norms
	Electrification of heating and cooking: shift to electric cooking and heat pumps	Improved health from gas-free living, possibly lower costs	Initial cost of shift
	Energy-efficient living: improve insulation, decrease energy waste, shift to LED lights, "heat people, not buildings"	Lower costs, increased comfort	Initial cost of shift, existing habits
	Renewable electricity: install household solar energy	Increased resilience to extreme weather and utility breakdown	Initial cost
Food	Plant-based diets: decrease intake of meat and dairy products	Improved health, lower food expenses	Food traditions, inadequate knowledge of plant-based foods
	Decrease food waste: mindful buying and consumption of food, minimizing waste	Lower food expenses	Busy lifestyle, decreasing food waste not a priority
Other	Avoid over-consumption: buy less, use second-hand goods where possible, and avoid short life–span products	Lower expenses	Social norms
	Join a climate activism group, including health care worker–specific groups	Provide a larger sense of purpose, opportunity to learn, social interactions	Time commitment
	Advocacy: including a planetary health lens in all professional activities, including advocating for sustainability in personal and professional lives	Provide a larger sense of purpose, serve as a role model	Burnout, fragmentation of health care, current incentives

Source: The authors

The Covid-19 pandemic has shown that we can rapidly operationalize social, economic, and behavioral changes in health care. We need to urgently employ similar approaches to operationalize the actions outlined in this article, involving each individual and department, to get close to a net-zero health care system.

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