McMaster University | HEALTH FORUM

Rapid Evidence Profile #37

(29 September 2022)

Question

What do we know from the best available evidence and experiences about the nature and scale of health-system emissions, mitigation and adaptation strategies to achieve net-zero health-system emissions, and processes to achieve net-zero health-system emissions?

What we found

To identify the best available evidence and experiences about the nature and scale of health-system emissions, mitigation and adaptation strategies to achieve net-zero health-system emissions and processes, we identified evidence as well as experiences from Australia, France, Germany, New Zealand, United Kingdom, select states of the United States (California, Massachusetts, Minnesota, New York and Oregon), and all Canadian provinces and territories (see Box 1 for a description of our approach). We organized our findings using the framework below.

Organizing framework

- Nature and scale of health-system emissions
  - IT partners
- Mitigation and adaptation strategies
  - Investments using a net-zero approach or requirement
  - Energy-use reductions
    - Buildings
    - Energy production
    - Industry partners (e.g., IT partners)
    - Land use
    - Transportation
  - Low- or zero-carbon electricity supply
    - Nuclear power
    - Renewable energy
  - Electrification and other fuel switching
    - Appliances
    - Supporting infrastructure
    - Vehicles
  - Non-energy emission solutions
    - Bio-sequestration

Box 1: Our approach

We identified evidence related to the question from the 17,105 documents included in a living evidence synthesis that used machine learning to map the global research on climate change and health. The dataset was last updated in December 2021. We added to the dataset – drawing from Social Systems Evidence and excluding duplicates – systematic reviews, rapid reviews or protocols for systematic reviews under the filter "climate action." Additionally, we performed an advanced search in PubMed using the words "emission" OR "waste" OR "ambulances" AND "health sector" OR "hospital" AND "climate change" OR "carbon footprint." Each of the 2,261 documents retrieved were assessed by one reviewer to ensure relevance to net-zero health-system emissions, and mitigation, adaptation, and processes. We identified jurisdictional experiences by hand searching government and stakeholder websites for information relevant to the question.

We appraised the methodological quality of full systematic reviews and rapid reviews that were deemed to be highly relevant using AMSTAR. Note that quality appraisal scores for rapid reviews are often lower because of the methodological shortcuts that need to be taken to accommodate compressed timeframes. AMSTAR rates overall quality on a scale of 0 to 11, where 11/11 represents a review of the highest quality. It is important to note that the AMSTAR tool was developed to assess reviews focused on clinical interventions, so not all criteria apply to systematic reviews pertaining to delivery, financial or governance arrangements within health systems or to broader social systems. We appraised the quality of the highly relevant guidelines using three domains in AGREE II (stakeholder involvement, rigour of development, and editorial independence) and classified guidelines as high quality if they were scored as 60% or higher on each domain.

This rapid evidence profile was prepared in the equivalent of three days of a 'full-court press' by all involved staff.

        - Carbon capture and storage
        - Fugitive-emission reduction
        - Industrial-process improvements
        - Reuse and recycling
    - Decarbonizing the supply chain
        - Food, catering and nutrition
        - Low-carbon inhalers
        - Anesthetic gases
- Processes, targets, and monitoring and evaluation strategy

We reviewed 2,261 abstracts and identified 75 evidence documents relevant to the question, of which we deemed 26 to be highly relevant. The highly relevant evidence documents include:

- seven full systematic reviews;
- one scoping review;
- one protocol for review already underway; and
- 17 single studies that provide additional insights.

We classified the 17 single studies as providing data analytics (n=8), qualitative insights (n=4), modelling (n=1), implementation/behavioural insights (n=3), and technology assessment/cost-effectiveness (n=1). In addition, the 26 highly relevant evidence documents were focused on

- health systems in general (n=4);
- health-system sectors
    - primary care (n=1), and
    - speciality care (hospitals and healthcare organizations (n=6), operating rooms (n=7), and emergency departments (n=1));
- infrastructure in health systems (imaging services (n=1), telemedicine (n=1), and ambulances (n=2)); and
- specific types of treatment or care that could be delivered within health systems (dentistry (n=1), outreach (n=1), and pharmaceutical industry (n=1)).

We outline in a narrative form below our key findings related to the question from highly relevant evidence documents and based on experiences from the selected jurisdictions (Australia, France, Germany, New Zealand, United Kingdom, select states of the United States (California, Massachusetts, Minnesota, New York and Oregon)) and Canadian provinces and territories. We provide additional details in Table 1 (the type and number of all documents identified according to the framework). In addition, details about evidence and experiences from the selected countries are provided in Table 2, and in Canadian provinces and territories in Table 3. A detailed summary of our methods is provided in Appendix 1, the full list of included evidence documents (including those deemed of medium and low relevance) in Appendix 2, and hyperlinks for documents excluded at the final stage of reviewing in Appendix 3.

Key findings from highly relevant evidence sources

We classified the studies included according to the framework developed for this rapid evidence profile. We identified evidence documents addressing the nature and scale of health-system emissions (one systematic review, one protocol for a scoping review and eight single studies), mitigation and adaptation strategies (seven systematic reviews, one scoping review and 15 single studies), and processes, targets, and monitoring and evaluation strategy (three single studies).

The richest findings about mitigation and adaptation strategies related to buildings, transportation, recycling and reuse, and anesthetic gases. As we noted above, the operating room was the most

common healthcare service addressed in the evidence documents. We did not find evidence documents related to: energy-use reductions related to energy production, industry partners, and land use; low- or zero-carbon electricity supply with nuclear power; electrification and other fuel switching related to supporting infrastructure; and non-energy emission solutions through bio-sequestration, and carbon capture and storage. Below, we provide insights where evidence in relation to the components of the organizing framework was identified.

Nature and scale of health-system emissions

One single study found that on a life-cycle basis, Canada's healthcare system was responsible for 33 million tonnes of carbon dioxide equivalents (CO_2e), which is 4.6% of the total national emissions. According to this modelling study, those emissions might represent a median estimate of 23,000 disability-adjusted life years (DALYs) lost annually from direct exposure to hazardous pollutants and environmental changes caused by pollution. Hospitals and prescription drugs each contribute approximately one-quarter of this total, and these findings are similar in the United Kingdom, Australia, and the United States. For instance, in Australia, hospitals and pharmaceuticals count for 70% of greenhouse gas (GHG) emissions, and the remaining 30% of the total carbon footprint came from the community or public health (6%), general practice (4%), dentistry (3%), aids and appliances (3%), other health practitioners (2%), research (2%), administration (2%), and patient transport services (1%).

One medium-quality systematic review found that high-income countries produce substantially more GHG emissions from surgical care than low- and middle-income countries. For example, emissions from minimally invasive surgery alone in the United States are estimated to be higher than the gross national emission of some countries.

One high-quality systematic review found that electricity was the largest source of GHG emissions in the operating room, accounting for 63%–78% of the carbon footprint of whole operations, and the amount of electricity consumed is likely to be closely linked with the operation duration. In this systematic review, two studies where electricity use was broken down found that the highest electricity consumption was for maintaining the operating room environment (heating, ventilation, and air-conditioning-HVAC). This was also highlighted in a medium-quality systematic review, which reported that operating rooms are highly energy-intensive due to their unique requirements for stringent temperature and ventilation control for patient safety and microbial control. At the same time, a low-quality scoping review indicated that HVAC requirements mainly depend on the hospital's geolocation and ambient temperature.

Mitigation and adaptation strategies

With respect to specific mitigation and adaptation strategies, we identify evidence documents addressing: investments using a net-zero approach or requirement (four systematic reviews and two single studies); energy-use reductions in buildings (six systematic reviews and one single study) and in transportation (five systematic reviews and three single studies); low- or zero-carbon electricity supply trough renewable energy (two systematic reviews and one single study); electrification and other fuel switching related to appliances (one systematic review and one single study) and connected to vehicles (three single studies); non-energy emission solutions related to industrial-process improvements (one systematic review and two single studies) and related to reuse and recycling (six systematic reviews and one single study); and decarbonizing the supply chain through food, catering and nutrition (one single study), through low-carbon inhalers (two single studies), and through anesthetic gases (three systematic reviews and two single studies).

Investments using a net-zero approach or requirement

Three systematic reviews (one high-, one medium- and one low-quality) found that despite the upfront costs of implementing strategies to reduce emissions, studies have demonstrated long-term cost savings. The best time to implement those strategies was identified as being during the planning and designing of new hospital buildings, where the initial capital costs have been found to represent less than 10% of total lifetime costs. One high-quality systematic review reported that energy consumption is the highest source of emissions in the operating room. However, it is also where healthcare workers have less impact, and it was therefore identified that institution directors should invest in the construction of sustainable operating rooms. One low-quality systematic review found no evidence of investments in emergency departments to reduce greenhouse gas emissions. One single study found that net-zero emission measures were most likely to be implemented if the hospital directors' board were sufficiently pressured by staff and reputational fears. Moreover, it was found that measures were more likely to be adopted if the potential impacts of such measures were perceived to align with broader organizational aims or possess more significant financial co-benefits. Another single study highlighted purchasing rules to encourage manufacturers and vendors to produce and sell safe and environmentally clean resources could be used as an approach by healthcare organizations to reduce emissions.

Energy-use reductions

Regarding energy-use reduction in buildings, we identified one low-quality systematic review that was focused on hospitals and five systematic reviews (three high quality, one medium quality and one low quality) focused on operating rooms within hospitals. At the hospital level, the low-quality systematic review reported several building interventions such as co-generation of energy (heat and power) using gas-fired co-generation, solar thermal cooling and ground-sourced heat pumps. One single study also suggested that hospital buildings should maintain appropriate internal temperatures in areas with different temperature needs, such as in emergency rooms and clinics, in contrast with the waiting rooms and the administration offices. This study also suggested using automatic doors in frequently used hospital entrances to minimize energy losses.

The operating room was the most common service addressed in the evidence documents reviewed, given that operating rooms have been identified as having the largest carbon footprint at the hospital level. The five systematic reviews addressing operating rooms were consistent in noting that the implementation of occupancy sensors or energy-efficient scheduling for using HVAC systems are essential strategies to reduce GHG emissions in the operating room. In addition, two systematic reviews (one high quality and one low quality) reported that radiofrequency identification systems, which automatically turn on and adjust themselves according to the number of persons in the operating room, have been shown in a pilot study that they perform correctly in 98–99% of the cases and could generate 50% energy saving. Other strategies for reducing GHG emissions were water-cooling systems, low-energy lighting, retrofitting insulation, energy-efficient windows, and heat or coolness recovery devices. One high-quality systematic review indicated that improving the energy efficiency of hospitals in the U.S. by 30% has been estimated to save $1 billion and a reduction in carbon emissions of 11 million tonnes. One low-quality systematic review reported no difference in the microbiological load of air samples from operating rooms where the ventilators are turned off or idle overnight compared with those with continuous ventilator usage.

Regarding the energy-use reduction in transportation, two systematic reviews (one high quality and one-low quality) indicated that staff/patient travel to the hospital is responsible for 10-37% of the carbon footprint in the healthcare sector. Strategies to reduce the carbon footprint due to transportation include technical changes oriented to encourage teleconferencing and telemedicine

(one high-quality, two medium-quality, one low-quality systematic reviews, one single study), improving public transport services, and encouraging car-pooling, cycling, and active travel (one high-quality, one medium-quality, one low-quality systematic reviews, two single studies), and setting limitations on or banning free parking inside the hospital premises (one single study).

One medium-quality systematic review focused on evaluating the carbon footprint of telemedicine reported a reduction greater than 95% in the carbon burden compared with in-person healthcare delivery. Carbon savings ranged from 0.69 kg CO2e (carbon dioxide equivalent) to 893 kg CO2e per encounter; distances saved ranged from 6.1 to 3,386 km, and cost savings went from 1.73 euros in fuel costs to over US$900 in travel-related expenses. One single study in Canada found that providing outreach clinics when healthcare is regionalized might reduce up to 2.5% of the individual's yearly carbon footprint.

Low- or zero-carbon electricity supply

One medium-quality and one high-quality systematic review indicated that surgical systems need to switch to renewable rather than fossil fuel-based energy sources, which cannot occur without overall energy-sector decarbonization. One single study performed in Greece found that the increase of renewable energy sources and gas-fired plants, and the shutting down of lignite-fired power plants in the country by 2028 will have a positive impact on reducing indirect GHG emissions in the healthcare sector.

Electrification and other fuel switching

Regarding electrification of appliances, one medium-quality systematic review found that the energy demand for lighting and machinery could be reduced by replacing older equipment with more energy-efficient options, such as light-emitting diode (LED) lights. One single study found that it is necessary for hospitals to gradually replace stationary air conditioning systems and freezers with appliances that are more energy efficient.

Regarding electrification and fuel switching of vehicles, three single studies (one data analytics, one implementation, and one economic evaluation) focused on the carbon footprint of ambulances. One study performed in Australia found that for ground ambulance operations, emissions averaged 22 kg of carbon dioxide equivalents per ambulance response. Vehicle fuels accounted for 58% of the emissions, with the remainder primarily attributable to electricity consumption. To reduce the carbon footprint of ambulances, two studies suggested using biofuels. Another study evaluated the possibility of electric ambulances, and one study recommended the use of hybrid vehicles for administrative and support-vehicle fleets. One study also suggested making changes in the routine use of ambulances, for instance, reducing unnecessary ambulance responses and transports, developing flexible response-time policies, reducing driving speeds when transporting stable patients without life-threatening conditions, and reducing ambulance idling at emergency scenes and receiving hospitals.

Non-energy emission solutions

Regarding industrial-process improvements, one high-quality systematic review found that the sterilization process can be done more efficiently and cleanly. The review indicated that although hospitals have modernized their sterilization process, opening the ability to reuse disposables, there is an evidence gap about the ecological impact of this change. When studies compare disposable and reusable devices, the process of sterilization of reusable devices results in equivalent or lower GHG emissions as compared to using disposable devices. Moreover, the review noted that a design permitting low-effort cleaning and sterilization, which decreases water and energy consumption for

reusable equipment, could be a promising lead for further reducing the environmental impact of sterilization.

One single study using data analytics reported the mean CO_2e emissions of the magnetic resonance (17.5 kg/scan), computed tomography (9.2 kg/scan), chest X-ray (0.8 kg/scan), and ultrasound (0.5 kg/scan). The study recommends that clinicians and administrators can reduce carbon emissions from diagnostic imaging by implementing different strategies when they are clinically appropriate. For instance, this can be accomplished by reducing unnecessary imaging, ordering low-impact imaging (X-ray and ultrasound) instead of magnetic resonance and computed tomography, turning off scanners to reduce emissions from standby power, and ensuring high utilization rates for scanners reducing standby times. One single study in the U.K. reported that pharmaceuticals contribute nearly a quarter of the CO_2 emitted each year by the health sector. Factors contributing to pharmaceutical carbon emissions include over-prescription, pharmaceutical waste, antibiotic resistance, routine prescriptions, non-adherence, drug dependency, lifestyle prescriptions, and drugs given due to a lack of preventive healthcare.

Six systematic reviews and one single study addressed reuse and recycling. Four of the systematic reviews focused on waste in the operating room. Three high-quality systematic reviews and one low-quality scoping review suggested switching to reusable items, reducing resource use where clinically appropriate, reprocessing surgical instruments, and improving waste segregation. One high-quality systematic review found that reprocessing single-use surgical instruments might reduce the GHG emissions of an entire operation by 9%, costing half the price of single-use equivalents. The same review also found several studies examining the carbon footprint of surgical scissors, laparotomy pads, and suction receptacles, showing that emissions can be reduced by 50%–97% through switching from single-use to reusable surgical devices. Another high-quality systematic review found that reusable items could substantially improve sustainability, with a 70% reduction in waste generation, threefold lower water consumption, and 2.5-fold lower energy consumption. One medium-quality systematic review highlighted strategies to maximize equipment lifespan and reduce emissions per use. According to this review, several studies have demonstrated reusable equipment to be environmentally superior to single-use devices (SUDs) for a wide range of equipment and procedures, potentially reducing GHG emissions by up to 90%. The review suggested that purchasing policies should be guided by environmental values, selecting equipment and consumables based on long-term financial and ecological costs rather than upfront costs.

A study reported that 13% of disposable items opened for neurosurgical procedures are discarded without use and, therefore, changing processes to only open equipment when needed and reducing the number of rarely used instruments could bring financial and carbon savings. A high-quality systematic review found six studies concluding that reusable textiles had substantially better environmental profiles than disposable textiles which increase energy use and carbon footprint by 200–300%. As one example, choosing reusable surgical gowns over disposable gowns reduced energy consumption by 64% and the carbon footprint by 66%. Moreover, the U.S. Centers for Disease Control and Prevention (CDC) concluded that no data suggests important differences between reusable and disposable gowns and drapes in terms of the prevention of surgical site infections.

One low-quality scoping review found that approximately 30% of all hospital waste is paper/cardboard and a similar proportion is plastic, indicating high recycling potential. In addition, two high-quality systematic reviews highlighted that recycling could usually be implemented as an extension of national domestic recycling programs.

On a broader scale, it has been estimated that streamlining and optimizing resource use in operating rooms can save approximately US$9 million per NHS trust in the U.K. each year. Reprocessing

single-use devices in the U.S. might save about US$20,000 per operating room annually. However, the move to single-use items has not been well studied, and decisions appear to be driven by factors other than infection control practices, such as cost, ease of use, difficulty making some reusable items patient-ready again, doctors' preferences, and marketing. In addition, one high-quality systematic review concluded that the use of reusables is only more sustainable if there is the infrastructure to efficiently reprocess the items. For instance, in Australia, reuse had monetary benefits, but it resulted in a 9% increase in emissions compared to the 84%, and 48% decreases seen in the U.K. and U.S., respectively. This difference is mainly due to Australia still having 75% of its electricity generated from coal which is a stark contrast to 1% in the U.K..

One single study performed in a large Western healthcare organization in Canada investigated how employees should engage with environmentally responsible use of resources at the workplace. The study found that organizational policies that discussed the utilization or conservation of healthcare resources did not mention the climate or environmental impact of these activities. However, waste-management policies were the only ones that explicitly prioritized reducing healthcare's environmental impact. Specifically, these policies aimed to reduce the potential for toxic chemical spills or other scenarios where possible environmental contamination could occur.

Decarbonizing the supply chain

One single study performed in Portugal addressed food, catering and nutrition, and found that, on average, each patient throws away 953 g of food each day, representing 35% of the food served. This equates to 8.7 thousand tonnes of food waste being thrown away each year at hospitals across Portugal. Based on this, five measures were identified to reduce food waste, which included bread on-demand, switching from a plated to a bulk system for meal delivery, allowing patients to choose a portion size, increasing menu options, and prompt update of empty beds to detect and record last-minute changes to the number of meals required.

Low-carbon inhalers were addressed in two single studies. One study found that suboptimal respiratory treatment, in the form of short-acting β2-agonists (SABAs) overuse across Europe and Canada, remains widespread and represents approximately two-thirds of total GHG emissions for respiratory treatment. The second study identified different strategies for reducing the carbon footprint of inhalers, including: reducing the use of short-acting beta-2 agonist (SABA) "on-demand" in all types of inhalers; supporting optimal use of the inhalation chamber; using inhalers for the last dose and not wasting doses by releasing the drug into the atmosphere; introducing inhalers with new propellants with lower global warming potential values; using rational replacement of metered-dose inhalers by dry powder inhaler or metered-dose liquid inhaler; and promoting the recycling of all inhalers.

Three systematic reviews and two single studies addressed anesthetic gases. One medium-quality systematic review reported that inhaled anesthetic agents are potent greenhouse gases, including desflurane which has the most significant global warming potential (more than 2,000 times that of CO_2), while another agent (sevoflurane) is only 130 times as potent as CO_2. Disproportionate use of desflurane has been found to be responsible for up to 80% of GHG emissions in operating rooms in high-income countries. As result, the review found that systematically switching from desflurane to sevoflurane can lead to a 10-fold reduction in carbon footprint and significant cost savings. In addition, two high-quality systematic reviews found that reducing the use of desflurane has a more powerful potential impact on global warming than other agents. One of these reviews reported that a combination of staff education, lower gas flows and promotion of IV anesthesia leads to a 25%–55% decrease in the usage of desflurane. The other review highlighted that healthcare workers should consider alternative anesthetic options such as local, regional, or total intravenous anesthesia after consultation with anesthesiologists. One single study in Australia also found that staff

education on desflurane-sparing practices, distribution of posters, and progressive removal of desflurane from operating rooms are effective strategies to reduce their use. After implementing these strategies, the number of desflurane bottles purchased decreased by 96%, the number of sevoflurane bottles bought increased by 6%, combined desflurane and sevoflurane emissions decreased by 88%, and costs decreased by 59%. One single study focused on dentistry services reported that reducing the use of nitrous oxide would be beneficial for the environment, but managing patients with nitrous oxide is often the only alternative to intravenous sedation or general anesthetic, both of which have a higher carbon footprint than nitrous oxide.

Processes, targets, and monitoring and evaluation strategy

One single study summarized and compared initiatives contained in three toolkits for implementing sustainability and resiliency measures for healthcare facilities. The study compared the Canadian Health Care Facility Climate Change Resiliency Toolkit, the U.S. Sustainable and Climate Resilient Health Care Facilities Toolkit, and the PAHO SMART Hospitals Toolkit of the World Health Organization/Pan American Health Organization. The study found that in Canada, six facilities in Nova Scotia, Ontario and Manitoba have piloted the toolkit. The study also reported that facilities that have used the toolkit had become essential agents of change for reducing fossil fuel emissions, improving resiliency to extreme weather events, and advocating for public understanding of climate change and health.

Educating providers on sustainability has been found to reduce the carbon footprint of the clinical practice of surgical-obstetric-anesthetic providers. Those strategies have reduced operating-room waste production by 50%, reduced GHG emissions from anesthesia care by 64%, and generated cost savings in high-income countries. The literature also recommends embedding climate change, recycling and waste segregation training into continuous medical education and routine training curricula.

Key findings from the jurisdictional scan

Our jurisdictional scan identified experiences about the nature and scale of health-system emissions, mitigation and adaptation strategies to achieve net-zero health-system emissions, and processes to achieve net-zero health-system emissions in Australia, France, Germany, New Zealand, United Kingdom, and select states of the United States (California, Massachusetts, Minnesota, New York, and Oregon) (Table 2), as well as all Canadian provinces and territories (Table 3). We summarize key findings below according to the categories in the organizing framework.

Nature and scale of health-system emissions

In Australia, 17% of GHG emissions in the health sector are direct emissions from sources controlled by the organization (e.g., hospital/care facility emissions, vehicle emissions). Indirect emissions from energy consumption (e.g., purchased electricity, steam, heating and cooling) are 12%. emissions from sources not directly controlled by the organization (e.g., supply chain), but directly related to its activities, including upstream and downstream consumables manufacture and transport (e.g., food, clothing, pharmaceuticals and chemical products) contributed to 71% of all health-sector emissions.

In the U.K., 62% of the total NHS carbon emissions in 2020 were from medicines, medical equipment and other supply chains (20% came from medicines and chemicals, 10% from medical equipment, 8% from non-medical equipment, and 24% from other supply chains). The direct emissions of NHS were 24%, building energy contributed 10%, water and waste 5%, anesthetic gases and metered doses inhalers 5%, and business, travel and NHS fleet 4%. Personal travel was

10% of the total NHS emissions; 5% came from patients' travels, 4% from staff commutes, and 1% from visitors' travels. The remaining 4% of total NHS emissions were due to commissioned health services outside NHS. In Canada, healthcare-related carbon emissions are responsible for 4.6% of the national GHG emissions. These are primarily due to hospitals, pharmaceuticals, and physician services emissions. Health sector emissions in France are 4.6% of the national emissions, are 3.6% in New Zealand, and are 5.2% in Germany, while in the U.S., the health sector contributes 8.5% of the national emissions, with an increase of 6% from 2010 to 2018.

Mitigation and adaptation strategies

Concerning specific mitigation and adaptation strategies, we identified actions taken in Australia, New Zealand, the U.K. and Alberta in Canada, which we summarize below in relation to the applicable categories from the organizing framework.

Investments using a net-zero approach or requirement

The Lancet Countdown on Health and Climate Change Policy Brief for Germany (2021) encourages healthcare facilities to report progress in reducing their carbon footprint, and calls on federal and state governments to provide appropriate funding for climate-protection investments. In other documents identified in the jurisdictional scan, there was no explicit mention of the necessary investments to decarbonize the health sector.

Energy-use reductions

Regarding reducing energy use in buildings, we identified that the U.K. supports constructing 40 new 'net-zero hospitals' as part of the new standards of the government's Health Infrastructure Plan. Additionally, the U.K. is completing a 50 million British sterling pounds LED lighting-replacement program and making heating-efficient interventions. In New Zealand, the Climate Change Response (Zero Carbon) Amendment Bill compels all buildings to operate at or near net-zero carbon. According to the document, the best option is to ensure new facilities are built by designing new energy-efficient, sustainable buildings that use a certified sustainability rating system such as Green Star. Other actions for the health sector in New Zealand include: reducing water consumption by improving technologies and policies; using materials that can be easily renewed; using green-insulation options such as sheep wool, shredded denim, hemp, and soybean foam to reduce heat and cooling needs; and installing double- or triple-glazed windows and passive solar design to minimize the need for heating. In Canada, the British Columbia government requires hospitals, schools, government offices and other public-sector organizations to record and report "in-scope" emissions, which include building energy, non-stationary (fleet) fuels and paper (packaged office paper). The B.C. government also ordered public-sector organizations to pay $25 per tonne to "offset" their emissions.

Regarding energy-use reduction by transportation, Australia, New Zealand and Alberta mention actions to incentivize home-based care and telemedicine to decrease patient transportation to and from health facilities. Those jurisdictions also mention working with transport agencies to establish safe, accessible, and convenient public transport links to healthcare facilities. In the U.K., the NHS offers reduced parking costs for car-sharing arrangements and increased bicycle parking spaces. In Australia, the Sydney South West Area Health Service has implemented a strategy to reduce car use by developing transport access guides for major trip generators. These guides illustrate how to travel to and from the hospitals using active travel by showing: where the cycle paths are; recommended walking routes from rail stations; locations of bus stops; and an indication of the frequency of buses.

Electrification and other fuel switching

Australia prioritized switching to renewable energy and reducing overall consumption. Additionally, Doctors for the Environment Australia recommended in their document Net zero carbon emissions: responsibilities, pathways and opportunities for Australia's healthcare sector, a target of 100% renewable electricity supply to all Australian hospitals by 2025 and no new gas installations or upgrades in Australian hospitals from 2021. In Alberta, one of the specific actions to decarbonize the health sector is accelerating the transition to carbon-neutral heat and electrical sources, supporting the development of a smart and green electrical grid, and establishing routines for auditing utilities.

Regarding fuel switching of vehicles, the U.K. is working towards road testing for what would be the world's first zero-emission ambulance by 2022. The U.K. plans to shift to zero-emission vehicles by 2032. In New Zealand, the Transport Agency is currently preparing a Safe and Environmentally Friendly Fleet Vehicle Procurement Policy, and is also working with the Sustainable Business Network to develop an e-bike purchasing scheme for large employers in the health sector. Australia and Alberta have also been working on transitioning fleet vehicles to electric and hydrogen sources of energy.

Non-energy emission solutions

Various actions regarding reuse and recycling were identified. Australia prioritized reducing waste through circular supply chains, as well as reducing overall consumption. In New Zealand, some specific actions are oriented toward reducing paper use, composting, recycling, educating staff about waste separation, and providing multiple bins with effective signage in locations of consumption. Alberta was the only jurisdiction that prioritized actions related to avoiding single-use products and transition to medical devices designed for reuse and repurposed for as long as possible. New Zealand accompanies these actions by educating patients, families and whānau in the community about treatment-related waste-minimization procedures (recycling, reusing, take-back schemes and community sharps disposal).

We identified specific actions related to managing water waste in hemodialysis. For instance, in Geelong, Australia, reverse osmosis reject water discarded from hemodialysis has been used in several innovative ways, both for in-centre and community satellite hemodialysis and home hemodialysis. These ways included reverse osmosis reject water redirection to the central sterilizing department for steam generation, hospital janitor stations and toilet flushers, hospital landscape use, community and aged-care garden watering, sporting ground and park maintenance. A similar experience was reported in Lyon, France, where after completing plumbing alterations to a three-level hemodialysis facility, reverse osmosis reject water was reused in building sanitation, which annually saved 1,200 m3 of reverse osmosis reject water. After offsetting the savings in water costs against the outlaid plumbing expenditure, the return on investment was recovered within 5.8 years.

Decarbonizing the supply chain

Australia and Alberta prioritized providing and promoting healthy diets from sustainable food systems. New Zealand has recommended different actions to decarbonize the supply of food, catering and nutrition in the health sector. Some of them include hospitals consulting with staff dietitians to develop alternative patient menus and encourage plant-based diets, discouraging the inclusion of red meat, buying local food which reduces greenhouse gas emissions from transportation, purchasing food from suppliers who use fewer pesticides and fertilizers, reducing

waste in service contracts and considering establishing programs to donate leftover edible food to food-rescue programs, composting organic food waste or using it as animal fodder.

The U.K. was the only jurisdiction that mentioned decarbonizing the health sector working with pharmaceutical suppliers to ensure that all of them meet or exceed the policy on net-zero emissions before the end of the decade 2020. In comparison, only Alberta included actions to transition from Metered Dose Inhalers (MDIs) to Dry Powdered Inhalers (DPI), initiating procurement contracts for low-GHG anesthetic agents, educating healthcare workers on low-GHG anesthetic techniques, and ceasing the use of desflurane immediately.

Processes, targets, and monitoring and evaluation strategy

We identified specific plans for decarbonizing the health sector in New Zealand and the U.K. In New Zealand, the Northland District Health Board has a goal to reduce absolute carbon emissions by 15% by 2025, compared with the 2016 baseline year. When growth is considered, this will likely require a total estimated 45%-65% reduction in its current emissions profile. Australia has a national net-zero emission plan and many experiences implementing different interventions at the hospital level; however, the healthcare sector has not been included in Australia's national climate response. In the U.K., the NHS propose two clear targets based on the scale of the challenge posed by climate change, current knowledge, and the interventions and assumptions that underpin this analysis. One is NHS reaching a net-zero emission by 2040 (NHS direct emissions), and the second is net-zero indirect emissions (emissions that NHS can influence) by 2045. The overall target is to reach an 80% reduction by 2036 to 2039.

In the Climate Action Plan 2050 of Germany, there is no specific mention of the health sector as a critical area of action, as only the energy, industry, buildings, transport, agriculture, land use and forestry sectors are mentioned. In France, the Shift Project 2021, elaborated by a consulting firm, aims to reduce greenhouse gas emissions from the health sector through 40 measures to decarbonize the health sector. We did not identify specific documents for decarbonizing the health sector in California, Massachusetts, Oregon, Minnesota or New York. However, in July 2022, more than half of the hospitals in Massachusetts pledged to cut greenhouse gas emissions by 50% by 2030 and reach net-zero emissions by 2050. Those hospitals in Massachusetts are among 650 healthcare companies and organizations nationwide making the same commitment in the U.S. In the document Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, there are descriptions of climate change risks to population health. Still, there is no explicit mention of actions to be implemented by the healthcare sector. Alberta was the only province with a document containing specific actions to decarbonize the healthcare sector. In the U.K., the NHS has already taken steps to reduce carbon footprint, including measuring, monitoring and displaying what energy is currently being used in health facilities. This was noted as having helped to increase carbon literacy and carbon numeracy of healthcare workers and patients, and reduce carbon use.

Table 1: Overview of type and number of documents that were identified about the nature and scale of health-system emissions, mitigation and adaptation strategies to achieve net-zero health-system emissions

Type of document	Guidelines (n=0)	Full systematic reviews (n=8)	Rapid reviews (n=0)	Protocols for reviews that are underway (n=1)	Titles/questions for reviews that are being planned (n=0)	Single studies (n=17)
Nature and scale of health-system emissions	-	4	-	1	-	5
IT partners	-	-	-	-	-	-
Mitigation and adaptation strategies	-	8	-	-	-	17
Investments using a net-zero approach or requirement	-	4	-	-	-	2
Energy-use reductions	-	7	-	-	-	3
Buildings	-	6	-	-	-	1
Energy production	-	-	-	-	-	-
Industry partners (e.g., IT partners)	-	-	-	-	-	-
Land use	-	-	-	-	-	-
Transportation	-	5	-	-	-	3
Low- or zero-carbon electricity supply	-	2	-	-	-	1
Nuclear power	-	-	-	-	-	-
Renewable energy	-	2	-	-	-	1
Electrification and other fuel switching	-	1	-	-	-	3
Appliances	-	1	-	-	-	1
Supporting infrastructure	-	-	-	-	-	-
Vehicles	-	-	-	-	-	3
Non-energy emission solutions	-	6	-	-	-	4
Bio-sequestration	-	-	-	-	-	-
Carbon capture and storage	-	-	-	-	-	-
Fugitive-emission reduction	-	-	-	-	-	-
Industrial-process improvements	-	1	-	-	-	3

Type of document	Guidelines (n=0)	Full systematic reviews (n=8)	Rapid reviews (n=0)	Protocols for reviews that are underway (n=1)	Titles/questions for reviews that are being planned (n=0)	Single studies (n=17)
Reuse and recycling	-	6	-	-	-	1
Decarbonizing the supply chain	-	3	-	-	-	5
Food, catering and nutrition	-	-	-	-	-	1
Low-carbon inhalers	-	-	-	-	-	2
Anesthetic gases	-	3	-	-	-	2
Processes, targets, and monitoring and evaluation strategy	-	-	-	-	-	3

Table 2: Experiences in selected jurisdictions on current readiness and capacity to address climate change and adjustments that are needed

Country	Summary of experiences
Australia	• Australia has a net zero emission plan, but so far, the healthcare sector has not been included in Australia's national climate response • The document The 'win win' pathway to net zero for the health sector suggests prioritizing the following actions: ○ Switch to renewable energy and reduce overall consumption ○ Support domestic production by sourcing locally and reduce waste through circular supply chains ○ Transition to virtual care models which reduce patient travel and the need for physical space ○ Transition to an electric vehicle (EV) fleet and promote green transport options for patients, staff and providers ○ Provide and promote healthy diets from sustainable food systems ○ Advocate for active lifestyles enabled by the built environment • Doctors for the Environment Australia in their document Net zero carbon emissions: responsibilities, pathways and opportunities for Australia's healthcare sector recommends six targets in the health sector: ○ Establishment of a national Sustainable Healthcare Unit (SHU) ○ 100% renewable electricity supply to all Australian hospitals by 2025 ○ No new gas installations or upgrades in Australian hospitals from 2021 ○ Reduction of healthcare demand through prioritizing preventive and primary care and sustainable models of care ○ Procurement of medical equipment, pharmaceuticals and goods with low-carbon footprints ○ Reduction in travel emissions through telemedicine and electric vehicle fleets

	• In Geelong, Australia, reverse osmosis reject water discarded from hemodialysis has been used in several innovative ways, both for in-centre and community satellite hemodialysis, and home hemodialysis
	  ○ These ways included reverse osmosis reject water redirection to the central sterilizing department for steam generation, hospital janitor stations and toilet flushers, hospital landscape use, community and aged-care garden watering, sporting ground and park maintenance
	  ○ Home-based patients reuse reverse osmosis reject water for domestic laundry and cleaning, toilet flushing, garden maintenance, and animal watering
	  ○ Renewable solar power arrays have been used to augment the dialysis-related power
	• In New South Wales, Australia, the Government Sustainability Policy proposed reducing greenhouse gas emissions from buildings; a 15% reduction in water usage; that all products and appliances purchased to be 4.5-energy-star rated; and a renewable energy target of 20% by 2020
	  ○ Blacktown, Mount Druitt and Nepean Hospitals are now generating 40–50% of their electricity onsite using cogeneration fired by natural gas; this has resulted in an average 15% reduction in electricity consumption across the Sydney West Area Health Service
	  ○ A strategy to reduce car use trialled by the Sydney South West Area Health Service has been the development of transport access guides for major trip generators such as hospitals
	  ○ These guides illustrate how to travel to and from the hospitals using active travel by showing: where the cycle paths are; recommended walking routes from rail stations; locations of bus stops; and an indication of the frequency of buses
	  ○ Health professionals have an important role in supporting an environment for change within the health sector and evidence from the NHS suggests that this is a role they would welcome

New Zealand	• It is estimated that New Zealand healthcare-sector emissions are 3.6% of the total emission in the country
	• The document Sustainability and the health sector: A guide to getting started, is a guide published by the Ministry of Health in New Zealand of which the objective is encouraging the health sector to take an active role in implementing sustainability as an integral part of its practice
	The guide emphasizes six specific action areas: waste, transportation, procurement, energy, food, and building design, and further description of actions recommended are below
	• Transport
	  ○ The New Zealand Transport Agency is currently preparing a Safe and Environmentally Friendly Fleet Vehicle Procurement Policy; it is also working with the Sustainable Business Network to develop an e-bike purchasing scheme for large employers
	  ○ Incentivizing home-based care or telemedicine for decreasing the amount of patient transportation to and from health facilities
	  ○ Work with local councils to establish safe, accessible, and convenient public transport links to healthcare facilities
	• Procurement

	○ New Zealand Government Procurement has proposed changes to the Government Procurement Rules, including a shift in focus towards public value as opposed to value for money ○ The new rules require agencies to support the transition to a net-zero emissions economy through the procurement of lower waste and low-emissions goods and services • Waste ○ Reducing paper use, and when possible, employers should provide electronic devices to enable paperless recording ○ Composting, recycling, and educating staff about waste separation, and providing multiple bins with effective signage in locations of consumption ○ Educating patients and their families and whānau in the community about treatment-related waste-minimization procedures (recycling, reusing, take-back schemes and community sharps disposal) ○ Replacing single-use items such as plastic water bottles, pill cups and drinking cups with reusable items ○ Using Blue-zone technology can help hospitals to make economic savings on anesthetic gases while preventing emission of harmful greenhouse gases • Energy ○ The Climate Change Response (Zero Carbon) Amendment Bill compels that all buildings will need to operate at or near net-zero carbon, with the best option of getting things right when new facilities are built ○ Designing new sustainable buildings, energy efficient, for instance, including low-emission heating technologies • Food ○ The health sector can work with staff dietitians to develop alternative patient menus and encourage plant-based diets, discouraging the inclusion of red meet ○ Buying local food which reduces greenhouse gas emissions from transportation ○ Purchasing food items from suppliers who use less pesticides and fertilizers ○ Reducing waste in service contracts and consider establishing programs to donate leftover edible food to food rescue programs, composting organic food waste or using it as animal fodder • Building design ○ All new builds, fit outs and renovations should use a certified sustainability rating system such as Green Star, which 'designs in' efficiencies and healthy buildings ○ Considering whole-of-life costing and life cycle, for instance, including materials that can be easily renewed, are sustainably managed and/or have production and disposal processes that are low in carbon emissions ○ Decreasing the need for heating and cooling, consider using green insulation options such as sheep wool, shredded denim, hemp, and soybean foam ○ Installing double- or triple-glazed windows and passive solar design can also reduce the need for heating ○ Reduce water consumption by improving technologies and policies, and encouraging staff, contractors, patients and visitors to get involved ○ Water reduction strategies include using efficient faucets, toilets, washing machines and shower heads, and switching from water-intensive film-based radiological imaging equipment to digital imaging
Germany	• It is estimated that the German healthcare-sector emissions are 5.2% of the total emissions in the country

	• In the Climate Action Plan 2050 there is no specific mention of the health sector as a key area of action, only the sectors of energy, industry, buildings, transport, agriculture, land use and forestry are mentioned • The Lancet Countdown on Health and Climate Change Policy Brief for Germany (2021) mentions some governmental actions to reduce the carbon footprint in Germany's health sector, which include: incentivizing awareness of medical societies and hospital associations and mobilize existing resources for climate protection measures; encouraging healthcare facilities to report progress in reducing their carbon footprint; and increasing the funding provided by federal and state governments for climate-protection investments
France	• The link between health and climate relies on INSERM and Santé Publique France, which are responsible for identifying and monitoring the effects of climate change on health risks, and for implementing measures to prevent these risks • The report published by Health Care Without Harm in 2019 presents a summary of the carbon footprint of the health sector in France with 29 MteqCO_2 per person, and this sector represents 4.6% of the national emissions in 2014; France stands out compared to other OECD countries thanks to the less carbon-intensive electricity matrix • The Shift Project 2021 in France aims to reduce greenhouse gas emissions from the health sector (MtCO2e) through 40 measures to decarbonize the health sector o The proposed measures include the relocation of certain essential molecules in Europe and the profound decarbonization of manufacturing and distribution processes, the reduction of the use of drugs by acting on prevention, the conditioning of the issuance of the Marketing Authorization (MA) to the publication of the carbon content of the drug or medical device, the reduction of the use of medical devices and their reuse when possible, the prohibition of anesthetic gases with a high greenhouse effect, and the development of telemedicine • Regarding specific interventions for hemodialysis, in Lyon, France, after completing plumbing alterations to a three-level building (for 173 hemodialysis patients), reverse osmosis reject water was reused in building sanitation, which annually saved 1,200 m3 (1.2 million litres) reverse osmosis reject water o After offsetting the savings in water costs against the outlaid plumbing expenditure, the return on investment was recovered within 5.8 years o This study concluded reuse of reverse osmosis reject water to be both viable and profitable
United Kingdom	• Delivering a 'Net Zero' National Health Service describes the early steps that NHS has taken to decarbonize the health sector, among them: o Developing a framework to evaluate carbon reduction associated with new models of care o Working with pharmaceuticals suppliers to ensure that all of them meet or exceed the policy on net-zero emissions before the end of the decade of 2020 o Working towards road-testing for what would be the world's first zero-emission ambulance by 2022, with a shift to zero-emission vehicles by 2032 feasible for the rest of the fleet o Ensuring the digital transformation to be a net-zero health service o Supporting the construction of 40 new 'net-zero hospitals' as part of the new standards of the government's Health Infrastructure Plan

	○ Completing a 50 million British sterling pounds LED lighting replacement program, and making heating-efficient interventions • The 2008 Climate Change Act for England has set a target of an 80% reduction in carbon emissions on 1990 baseline levels by 2050; to achieve this target, a transformational change is required by the health sector • The steps the NHS has already taken to reduce carbon include measuring, monitoring, and displaying what energy is currently being used in health facilities ○ This has helped to increase carbon literacy and carbon numeracy of healthcare workers and patients, and reduce carbon use ○ Another strategy is to promote low-carbon transport like car sharing by offering reduced parking costs for car-sharing arrangements; as in all change programs, there must be an immediate benefit to those doing the changing ○ Prominent programs like car sharing or parking spaces for bicycles also send a visible and important message to the public that the health system takes carbon reduction seriously • The Green Nephrology (GN) initiative, established in 2009 within the National Health Service Sustainable Healthcare program, has systematically documented and implemented "green practices" across the whole U.K. dialysis spectrum ○ This program has changed both the appreciation of and attitudes toward resource conservation, reusability and waste management throughout the United Kingdom in a three-to-four-year time frame • Water conservation and, where possible, reuse makes economic sense; the GN group has estimated "annual savings to the U.K. health services of 7 million British sterling pounds (8.2 million euros; US$11 million), 11,000 t CO2-eq of greenhouse gases, and 470 million liters of water • The NHS Sustainable Development Unit, Global Green and Healthy Hospitals and the Campaign for Sustainable Healthcare websites provide numerous resources and case examples of interventions in the health sector to achieve net-zero emissions
California – U.S.	• The document Achieving Carbon Neutrality in California does provide a specific approach for the health sector • CARB, the lead agency for climate change programs and that oversees all air pollution control efforts in California, published a climate action plan in 2020; the Draft 2022 Scoping Plan does not include the health sector
Massachusetts – U.S.	• The Massachusetts Clean Energy and Climate Plan for 2025 and 2030 makes no specific mention of targets for the health sector • However, Health Care Without Harm-Massachusetts released a report on behalf of Boston's Green Ribbon Commission Health Care Working Group in July 2021, revealing that local healthcare facilities cut GHG emissions by 18% from 2011 through 2019, despite serving more patients and expanding facility space • The report summarizes more than 40,000 energy and GHG records, identifies key actions behind reductions, and tracks the healthcare sector's collective progress towards the climate goals shared by the City of Boston and Green Ribbon Commission • In July 2022, more than half of the hospitals in Massachusetts pledged to cut greenhouse gas emissions by 50% by 2030, and reach net-zero emissions by 2050; they're among 650 healthcare companies and organizations nationwide making the same commitment

Oregon – U.S.	• The Oregon Global Warming Commission Reports, which are used as a platform to educate and inform legislators and the public about current critical climate facts, policies, and strategies, do not explicitly mention actions for the health sector ○ The last report (published 2021) is focused on natural and working lands, and the three previous biennial reports (published in 2020, 2018, 2017) did not mention specific recommendations for the healthcare sector
Minnesota – U.S.	• The Minnesota Climate Action Framework does not make explicit mention of actions for the healthcare sector
New York – U.S.	• New York presents in the document Pathways to Carbon-Neutral NYC: MODERNIZE, REIMAGINE, REACH (published in 2021), proposals for achieving the goal of net-zero emissions ○ The document addresses buildings and industry, transportation, electricity, natural gas, district energy and waste; however, the document does not explicitly mention interventions or actions for the healthcare sector

Table 3: Experiences in Canadian provinces and territories on current readiness and capacity of public-health systems to address climate change and adjustments that are needed

Province	Summary of experiences
Pan-Canadian	• The Canadian Coalition for Green Health Care compiles different resources and documents about climate-related hazards and their implications for healthcare services ○ The webpage of this organization mentions that a Pan-Canadian Framework on Clean Growth and Climate Change is in progress, and that provincial, territorial, and federal governments are working together to reduce greenhouse gas emissions; however, there no specific actions for the health sector were identified • In the document Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, there are descriptions of climate change risks on population health, but there is not an explicit mention of actions to be implemented by the healthcare sector
British Columbia	• B.C. has climate legislation in the Greenhouse Gas Reduction Targets Act (Province of British Columbia 2007) ○ Starting in 2010, the B.C. government required public sector organizations (PSOs) to be carbon neutral through emissions reductions and purchasing offsets ○ Hospitals, schools, government offices and other PSOs must record and report "in-scope" emissions and pay $25 per tonne to "offset" their emissions ○ The three in-scope categories are building energy, non-stationary (fleet) fuels and paper (packaged office paper); since 2010, all government and public-sector new buildings must be rated LEED© Gold (Leadership in Energy & Environmental Design) or higher • In its first five years, there is evidence the B.C. government's carbon-reduction strategy is working to reduce emissions ○ The report Leading by Example: The First Five Years of Carbon Neutral Government in British Columbia – 2010–2014 (Province of British Columbia 2015) states: "The BC public sector has met this goal. We have measured our carbon emissions, and through a combination of emission reductions and offsets, have been the only government at the federal, provincial or state level in North America to operate with net-zero greenhouse gas emissions."

Alberta	• The document Building climate-resilient and sustainable healthcare: A plan of action for Alberta Health proposes specific actions to decarbonize the healthcare sector, among them: ○ Accelerate transition to carbon-neutral heat and electrical sources, support development of a smart and green electrical grid, and establish routines for auditing utilities ○ Prioritize access to community-based healthcare and telemedicine ○ Transition fleet vehicles to electric and hydrogen as local economies in these areas accelerate ○ Incentivize public and active transport to healthcare facilities for patients and employees ○ Avoid single-use products and transition to medical devices designed for reuse and repurposed for as long as possible ○ Transition towards more plant-based diets that are in line with standard dietary guidelines ○ Move from Metered Dose Inhalers (MDIs) to Dry Powdered Inhalers (DPI) ○ Initiate procurement contracts for low-GHG anesthetic agents, educate caregivers on low-GHG anesthetic techniques, and cease the use of desflurane immediately
Saskatchewan	• In the document Building the Low Carbon Economy: Exploring Opportunities and Challenges for Saskatchewan there is no explicit mention of actions for the health sector
Manitoba	• No specific documents or policies oriented to the health sector were identified; however, Manitoba's Climate Change and Green Economy Action Plan (2015) describes some provincial interventions that have an impact on the health sector, for instance: ○ The leadership in geothermal heating and cooling with over 13,000 heat pump units installed throughout the province ○ Investing in public transit and active transportation to the development of rapid transit in Winnipeg, and created the Small Communities Transportation Fund to support active transportation and mass transit throughout the province ○ New Flyer Industries, based in Winnipeg, is a leading manufacturer of electric and hydrogen fuel cell buses in North America; zero-emission battery-electric propulsion transit buses significantly reduce GHG emissions and local air contaminants
Ontario	• One of the goals of Ontario´s Climate Change Strategy is having enhanced emissions reductions in government facilities and operations by 2030 ○ The public sector – including municipalities, hospitals, schools and universities – will have started to significantly reduce their carbon emissions; however, the document does not describe previous or current experiences • The Ontario Climate Change and Health Toolkit addresses the public-health challenges of a changing climate in Ontario, but does not include actions to reduce the carbon footprint in the healthcare sector
Québec	• The webpage 2030 Plan for a Green Economy contains different initiatives of the provincial government ○ The documents Plan de mise en oeuvre 2022-2027 du Plan pour une économie verte 2030 and 2030 Plan for a Green Economy do not include specific actions or experiences within the health sector
New Brunswick	• Transitioning to a Low-Carbon Economy - New Brunswick's Climate Change Action Plan Progress Report 2022 provides a full report of 118 actions that the provincial government is pursuing to have a net-zero emission economy

	○ Although no specific mention of the health sector, action #17, "Improve the energy performance of all existing government-owned buildings, including offices, schools, hospitals and affordable housing," is marked as not completed, and the report does not mention any progress at the hospital level ○ Action #19, "Phase out the use of fuel oil for heating publicly funded buildings and replace it with low-carbon fuels such as wood pellets, natural gas, biomass and solar energy," is marked as not completed, but the report describes that the Upper River Valley Hospital biomass boiler plant was brought online in December 2021; this installation is expected to reduce the hospital's oil consumption by over 440,000 litres annually, resulting in a GHG reduction of 1,220 tonnes
Nova Scotia	• The Environmental Goals and Climate Change Reduction Act – Annual Progress Reporting does not make specific mention of the healthcare sector; however, the article seven of the Environmental Goals and Climate Change Reduction Act, requires that any new build or major retrofit in government buildings, including schools and hospitals, that enters the planning stage after 2022, to be net-zero energy performance and climate resilient
Prince Edward Island	• The document 2040 Net Zero Framework (2022) Accelerating Our Transition to a Clean, Sustainable Economy does not mention the health sector
Newfoundland and Labrador	• In different documents and reports available on the webpage NetZero Project of the Newfoundland and Labrador government, the last three documents (Offshore Renewables: Feedback on NRCan Technical Requirements Paper, Identifying R&D strengths of the region that could support more cleantech development and adoption within the industry, and Understanding the innovation system and what gaps exist in supporting cleantech development and adoption) do not mention specific actions or experiences in the health sector
Yukon	• The report of the government of Yukon "Informing the development of Our Clean Future: a Yukon strategy for climate change, energy and a green economy" does not make explicit mention of the health sector
Northwest Territories	• The document 2030 Energy Strategy: A Path to More Affordable, Secure and Sustainable Energy in the Northwest Territories does not include specific actions for the health sector
Nunavut	• According to 2018 March Report of the Auditor General of Canada to the Legislative Assembly of Nunavut regarding climate change, the Government of Nunavut had strategies for adapting to climate change and managing its energy use, but lacked plans to implement them

Vélez CM, Wilson MG, Lavis JN. Rapid evidence profile #37: What do we know from the best available evidence and experiences about the nature and scale of health-system emissions, mitigation and adaptation strategies to achieve net-zero health-system emissions, and processes to achieving net-zero health-system emissions? Hamilton: McMaster Health Forum, 26 September 2022.

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Appendices for Rapid Evidence Profile #37

(29 September 2022)

Appendix 1: Methodological details

Identifying research evidence

To identify evidence about the current readiness and capacity of Canadian federal, provincial and territorial (FPT) public-health systems to address climate change, and how they need to adjust their public-health functions and system features to do so, we used data from a living evidence synthesis that identified 17,105 documents as of the end of 2021. Of these documents, 1,374 mentioned emissions, healthcare sector and carbon footprint. Each of the 1,374 documents were assessed by a single reviewer to identify those relevant to the question. In addition, each of the included single studies were categorized by one reviewer according to the forms of evidence profiled in the Evidence Commission report (data analytics, modelling, evaluation, behavioural/implementation, and/or qualitative insights).

We supplemented this dataset by drawing on Social Systems Evidence and excluding duplicates that had already been included from the living evidence synthesis. In Social Systems Evidence, we used filters under programs and services for "climate action," "environmental conservation," "food safety and security," and "natural resources." We combined these with key words searches for "climate change" AND (health OR public health). Additionally, we performed an advanced search in PubMed using the words "emission" OR "waste" OR "ambulances" AND "health sector" OR "hospital" AND "climate change" OR "carbon footprint". A single reviewer assessed these documents for inclusion to ensure they related to the question.

Assessing relevance and quality of evidence

We assess the relevance of each included evidence document as being of high, moderate or low relevance to the question. We then use a colour gradient to reflect high (darkest blue) to low (lightest blue) relevance.

Two reviewers independently appraised the methodological quality of systematic reviews and rapid reviews that are deemed to be highly relevant. Disagreements are resolved by consensus with a third reviewer if needed. AMSTAR rates overall methodological quality on a scale of 0 to 11, where 11/11 represents a review of the highest quality. High-quality reviews are those with scores of eight or higher out of a possible 11, medium-quality reviews are those with scores between four and seven, and low-quality reviews are those with scores less than four. It is important to note that the AMSTAR tool was developed to assess reviews focused on clinical interventions, so not all criteria apply to systematic reviews pertaining to health-system arrangements or to economic and social responses. Where the denominator is not 11, an aspect of the tool was considered not relevant by the raters. In comparing ratings, it is therefore important to keep both parts of the score (i.e., the numerator and denominator) in mind. For example, a review that scores 8/8 is generally of comparable quality to a review scoring 11/11; both ratings are considered 'high scores.' A high score signals that readers of the review can have a high level of confidence in its findings. A low score, on the other hand, does not mean that the review should be discarded, merely that less confidence can be placed in its findings and that the review needs to be examined closely to identify its limitations. (Lewin S, Oxman AD, Lavis JN, Fretheim A. SUPPORT Tools for evidence-informed health Policymaking (STP): 8. Deciding how much confidence to place in a systematic review. *Health Research Policy and Systems* 2009; 7 (Suppl1):S8.

Preparing the profile

Each included document is hyperlinked to its original source to facilitate easy retrieval. For all included guidelines, systematic reviews, rapid reviews and single studies (when included), we prepare declarative headings that provide a brief summary of the key findings and act as the text in the hyperlink. Protocols and titles/questions have their titles hyperlinked given that findings are not yet available. We then draft a brief summary that highlights the total number of different types of highly relevant documents identified (organized by document), as well as their key findings, date of last search (or date last updated or published), and methodological quality.

Appendix 2: Key findings from evidence documents that address the question, organized by document type and sorted by relevance

Type of document	Relevance to question	Key findings	Recency or status
Guidelines	None identified		

Full systematic reviews	• Nature and scale of health-system emissions
	  ○ IT partners
	• Mitigation and adaptation strategies
	  ○ Investments using a net-zero approach or requirement
	  ○ Energy-use reductions
	  ▪ Building
	  ▪ Transportation
	  ○ Low- or zero-carbon electricity supply
	  ▪ Renewable energy
	  ○ Electrification and other fuel switching
	  ▪ Appliances
	  ○ Non-energy emission solutions
	  ▪ Reuse and recycling
	  ○ Decarbonizing the supply chain
	  ▪ Anesthetic gases
	• Processes, targets, and monitoring and evaluation strategy
		• Surgical care provision can be carbon intensive, the health sector contributes about 4.9% of total global greenhouse gas (GHG) emissions
		• Operating rooms (ORs) are a highly resource-intensive component of the health system, they can be three to six times more energy-intensive than the hospital average and consume 40–60% of a facility's supply chain
		• The main sources of GHG emissions from surgical procedures are equipment and consumables, inhaled anesthetic agents, and energy use; studies have shown that a combination of measures targeted at different sources can reduce the carbon footprint of ORs by 80–95%
		• Surgical system strengthening is essential in response to rising disease burdens from climate change, such as injuries from natural disasters
		• This review explored how climate change could be integrated into national surgical planning in the Western Pacific region; the review included 220 articles
		• Findings were categorized using the modified World Health Organization Health System Building Blocks Framework
		• Infrastructure
		  ○ Operating theatres are highly resource-intensive; their carbon footprint could be reduced by maximizing equipment longevity, improving energy efficiency, and renewable energy use
		  ○ Most emissions arise from the manufacturing process, therefore, there are important strategies to maximize equipment lifespan and reduce emissions per use; several studies have demonstrated reusable equipment to be environmentally superior to single-use devices (SUDs) for a wide range of equipment and procedures, potentially reducing GHG emissions by up to 90%
		  ○ Environmentally preferable purchasing policies could guide the selection of equipment and consumables based on their long-term financial and environmental cost rather than their upfront cost
		  ○ The number of instruments opened per case can be reduced to the minimum required; Thiel et al. found that minimizing the number of SUDs opened decreased GHG emissions in laparoscopic surgery (excluding anesthesia) by 70% in a United States hospital
			Literature last searched April 2021

		○ A more parsimonious approach to surgical trays has been demonstrated to be feasible and cost-effective ○ ORs are highly energy-intensive due to their unique requirement for stringent temperature and ventilation control for patient safety and microbial control; occupancy sensors or energy-efficient scheduling, such as adapted weekend settings, could reduce HVAC energy consumption when ORs are not in use ○ The energy demand for lighting and machinery could be reduced by replacing older equipment with more energy-efficient options, such as light-emitting diode (LED) lights ○ Health systems with carbon-intensive electricity sources have significantly greater GHG emissions from energy use and surgical equipment reprocessing; this emphasizes that surgical system sustainability cannot happen in isolation without general energy sector decarbonization ○ Building climate-resilient infrastructure involves the whole health system and may, in some cases, necessitate relocating entire health facilities from disaster-prone sites ○ ORs are particularly vulnerable to climate extremes due to their strict ventilation and temperature requirements; white reflective roofs, retrofitting insulation, energy-efficient windows, and heat or coolness recovery devices could improve both OR energy efficiency and resilience to temperature extremes • Service delivery ○ Inhaled anesthetic agents are potent greenhouse gases; among them, desflurane has the greatest global warming potential (GWP), more than 2,000 times that of carbon dioxide (CO2), while sevoflurane is only 130 times as potent as CO2 ○ While patient safety must be the primary driver for anesthetic care delivery, several strategies could reduce its GHG emissions ○ Disproportionate use of desflurane has been found to be responsible for up to 80% of GHG emissions in ORs in high-income countries (HICs); systematically switching from desflurane to sevoflurane can lead to a 10-fold reduction in carbon footprint and significant cost savings ○ The use of volatile anesthetic agents could be profoundly limited by preferentially using total intravenous anesthesia and regional anesthesia when appropriate, regional anesthesia could have additional advantages in low-resource and hard-to-reach settings, including cost, safety, OR efficiency, and the potential for task-shifting to non-specialist providers, thereby improving access as well as sustainability ○ Using low fresh gas flow or closed-circuit delivery can reduce the volume of volatile gas consumed by 20% ○ New technologies, such as Dynamic Gas Scavenging Systems or silica zeolite, can absorb, destroy, and even recycle anesthetic waste gases	

		○ The mode of surgical care delivery can also alter its carbon footprint, primarily due to CO_2 use for insufflation and a greater number of single-use instruments ○ However, the mode of surgery depends on clinical conditions, and some are more effective in preventing complications and improving prognosis, therefore, studies examining long-term environmental impact are required before conclusions could be drawn; the mode of surgery should be selected primarily based on clinical indications ○ Laparoscopic surgery has proven clinical benefits over open surgery in many circumstances; however, environmental impact should weigh more heavily into consideration where there is clinical equipoise, such as between robotic and laparoscopic surgery ○ Innovative service-delivery models such as telemedicine and mobile outreaches have been found to reduce GHG emissions from patient travel while offering more accessible, patient-centred care ○ Office-based procedures when appropriate (i.e., skin procedures) • Workforce ○ Educating SOA (surgical-obstetric-anesthesia care) providers on sustainability has been found to reduce the carbon footprint of their clinical practice, focused educational initiatives have been successful in reducing OR waste production by 50%, and GHG emissions from anesthesia care by 64%, and generated cost savings in HICs ○ The literature also recommends embedding climate change into continuous medical education and routine training curricula; successful education programs have used personal narratives for emotional appeal and targeted the multidisciplinary team • Information management ○ Environmental sustainability should be incorporated as a key performance indicator for surgical systems in addition to other indicators • Research ○ Most of the studies included in this review have been conducted in HICs; aside from a few well-researched areas, such as heat-related birth outcomes and anesthetic gases, the evidence on this topic is still limited and dominated by commentaries and opinion pieces • Finance ○ Strategies to reduce emissions in SOA care often have significant financial co-benefits ○ Despite the upfront cost of capital purchases, studies have demonstrated substantial long-term cost savings from measures, such as improving building energy efficiency, reprocessing instruments, anesthesia gas scavengers, and telemedicine	

		○ The results of life-cycle economic and environmental analyses must be considered by hospital managers, donors, and financial mechanisms in supporting sustainable infrastructural upgrades • Governance ○ At facility level, institutional practices in procurement, energy use, and service design should be shifted towards sustainability; environmentally preferable purchasing policies should be developed to guide sustainable procurement decisions ○ At national level, strategic planning in surgical system strengthening, climate change mitigation and adaptation, and disaster risk reduction should be closely integrated ○ Regulation and policies should facilitate sustainability where possible; for instance, SUD reprocessing can lead to environmental and cost benefits and is increasingly used in both HICs and low- and middle-income countries (LMICs) ○ SUD reprocessing is prohibited in many countries despite being shown to be safe in approved contexts; with more evidence being generated in the future, regulations could be updated to delineate the appropriate parameters around its use ○ At the international level, HICs produce substantially more GHG emissions from surgical care than LMICs; for instance, emissions from minimally invasive surgery alone in the United States are estimated to be higher than the gross national emission of some countries ○ HICs in the region have both the responsibility and the ability to make a significant contribution to climate change mitigation by transforming their surgical systems Source (AMSTAR rating 5/9)	
	• Mitigation and adaptation strategies ○ Energy-use reductions ▪ Building ▪ Transportation ○ Low- or zero-carbon electricity supply ▪ Renewable energy ○ Non-energy emission solutions ▪ Reuse and recycling	• The U.S. healthcare sector produces 655 million tons of CO2 equivalents per year, contributing 8–10% of all national GHG emissions • In the U.K., the National Health Service (NHS) generates 22.8 million tons of CO2 per year, responsible for 6% of U.K. net CO2 emissions, and one quarter of all those produced by the public sector • Operating rooms make a large contribution to the healthcare carbon footprint as they are typically the most resource-intensive area of a hospital • Of U.K. NHS CO2 emissions, 59% are associated with the supply chain, of which the largest hotspot is medical instruments and equipment (responsible for 15.5% of total emissions) • Operating rooms generate 21–30% of hospital waste and are three to six times more energy-intensive than the rest of the hospital, which can be largely attributed to maintenance of the theatre environment (heating, ventilation, and air-conditioning) • This systematic review used a life-cycle assessment (LCA), a method used to account for several different environmental indicators (such as GHG emissions, eutrophication, and	Literature last searched August 2019

		ecotoxicity); only the carbon footprint component of LCA studies was considered in this review, and eight studies were included • The processes that are included within study inventory boundaries were classified according to GHG emission types (scope 1–3); scope 1 emissions are those directly emitted from a given organization (e.g., anesthetic gases), scope 2 emissions are indirect GHG emissions associated with electricity used by an organization (i.e., purchased directly by the hospital), and scope 3 gases incorporate all other indirect emissions (including those embedded within the supply chain, travel, and waste disposal) • A carbon footprinting study is most reflective of true emissions where all processes attributable to the functional unit (from all 3 scopes) were included • The study found that the carbon footprint of a single operation ranged from six to 814 kg carbon dioxide equivalents • The studies found that major carbon hotspots within the examined operating theatres were electricity use, and procurement of consumables • Electricity was the largest source of GHG emissions, accounting for 63–78% of the carbon footprint of whole operations, and the amount of electricity consumed is likely to be closely linked with the operation duration • In two studies where electricity use was broken down, the highest consumption of electricity was for maintaining the theatre environment (heating, ventilation, and air-conditioning) o Approaches to minimizing electricity use include developing and installing occupancy sensors, low-energy lighting, energy efficient air-conditioning systems, and water-cooling systems o Improving the energy efficiency of U.S. hospitals by 30% has been estimated to save US$1 billion and a reduction in carbon emissions of 11 million tons o Electricity should also be switched to renewable rather than fossil fuel-based sources • By contrast, four studies found procurement to be the largest hotspot, with three specifically identifying single-use items to be largest contributors, responsible for up to 78% of the carbon footprint (with two of these studies referring to the same dataset) o Attention should be given to reducing this footprint, for example through switching to reusable items and reducing resource use where clinically appropriate, and considering reprocessing of surgical instruments o Studies examining the carbon footprint of surgical scissors, laparotomy pads, and suction receptacles found that this can be reduced by 50–97% through switching from single-use to reusable surgical devices o This is consistent with reports that favour reusable rather than disposable perioperative textiles, and anesthetic items (anesthetic drug trays, laryngeal mask airways, and laryngoscope handles and blades)	

		○ Reprocessing of single-use surgical instruments is another potential target, modelled to reduce the GHG emissions of an entire operation by 9%, and costing half the price of single-use equivalents; however, reprocessing is not widely used in countries such as the U.K. or Australia ○ Seven single-use medical devices (including endoscopic trocars, ligature, arthroscopic shavers, and ultrasonic scalpels) found that reprocessed devices conferred lower global warming impacts alongside financial benefits ○ There is potential from streamlining surgical instrument trays through minimizing material use and selecting reusable surgical instruments ○ One study reported that 13% of disposable items opened for neurosurgical procedures are discarded without use, hence changing processes to only open equipment when needed could bring financial and carbon savings ○ On a broader scale, it has been estimated that streamlining and optimizing resource use in operating theatres holds the potential to save 7 million British sterling pounds (approx. US$9 million) per NHS trust in the U.K. each year • In the two studies that accounted for patient and staff travel to hospital, this was responsible for 10–37% of the footprint • It was possible to reduce the carbon footprint of surgery through improving energy-efficiency of theatres, using reusable or reprocessed surgical devices and streamlining processes Source (AMSTAR rating 9/10)	
	• Mitigation and adaptation strategies ○ Investments using a net-zero approach or requirement ○ Energy-use reductions ▪ Building ▪ Transportation ○ Non-energy emission solutions ▪ Reuse and recycling	• The objective of this review was to establish the extent to which hospital environmental sustainability has been studied and the key issues that emerge for policy, practice and research; 76 studies were included in this review • Common research themes were identified: hospital design, direct energy consumption, water, procurement, waste, travel and psychology and behaviour • Some countries (particularly the United Kingdom) have begun to invest systematically in understanding the environmental effects of hospitals • We found large variability in the extent of the evidence base according to topic; research regarding the architectural fabric of hospital buildings is at a relatively mature stage • Similarly, there is a developed research base regarding devices and technologies used within hospitals to reduce the environmental effects of direct hospital energy and water use • A significant part of the environmental footprint of hospitals relates to clinical practice, e.g., decisions regarding the use of pharmaceuticals and medical devices	Literature last searched October 2013

		• The effects of preventive or demand management measures which avoid unnecessary hospital procedures are likely to be much greater than incremental changes to how hospital procedures are performed
		• Hospital design
		  o The initial capital costs of a hospital building represent less than 10% of full lifetime costs
		  o This indicates the importance of incorporating energy efficiency at the planning and design stage for securing longer-term efficiencies
		  o Single patient rooms may be associated with reduced infection rates, but have greater initial costs and energy requirements compared with multiuse patient rooms; two reviews suggested that the benefits of single patient rooms are not yet proven, and that further research is needed to investigate the balance of costs and benefits
		• Energy
		  o Heating, ventilation and air conditioning typically account for at least half of direct hospital energy usage, with lighting and equipment accounting for most of the remainder
		  o Hospital ventilation is routinely left running continuously, including within ORs that are unoccupied overnight; there is, however, evidence of no difference in the microbiological load of air samples from ORs where the ventilators are turned off in idle ORs overnight, compared with ORs with continuous ventilator usage
		• Water
		  o Hospitals use considerable amounts of water – e.g., 1% of a city's total water consumption
		  o Within a hospital most of the water use occurs in four areas: wash basins, sinks and showers (20–40% of total), toilets (15–30%), laboratories, cooling towers, macerators and sterilizers (15–40%) and food preparation (5–25%)
		  o Water savings of 10–25% can be achieved through simple means which do not require further innovations or research: auditing usage including installing data-logging metres and sub-metering, checking for leaks, applying flow restrictors on hand basins and showers, installing dual-flush toilets and reclaiming water from dialysis units and sterilizers
		  o Significant water savings are possible (hundreds of litres/tap/day) from altering the surgical hand scrub whether through water-saving devices such as automatic tap timers or replacing water use with other disinfectants
		• Travel
		  o Hospital travel incorporates ambulance, private and public transport, and car travel is a major contributor to CO2 emissions; it is estimated that 16% of carbon emissions related to healthcare are attributable to staff/patient travel	

		○ The research agenda for improving the sustainability of hospital travel can be subdivided into technical, financial and social ○ Technical changes may lead a transformation of hospital travel; improved teleconferencing/telemedicine can reduce travel demand for business, patient and staff leading to financial, environmental and time savings ○ Large reductions in car transport to hospitals are possible with improved public transport services, car-pooling and encouraging cycling ○ For example, at Addenbrooke's hospital, Cambridge, U.K., by doubling the number of bus services and greatly improving hospital bicycle facilities the proportion of journeys made by car was reduced from 60% in 1999 to 38% in 2006 ○ Social norms and peer influence within the hospital workforce may shape staff decisions regarding how to travel to work • Procurement ○ Several studies have found that procured goods represent by far the largest contributor to healthcare's carbon footprint ○ The research base examining the environmental effects of hospital procurement is far less developed than for hospital architecture and engineering ○ Costs of materials include: the energy, water, petrochemical costs and pollution produced in obtaining raw materials, manufacturing, transportation, use, reuse, maintenance, recycling and waste disposal ○ In the operating theatre, reusable variants of medical devices were found to be less expensive and had lower environmental effects (CO_2 emissions, water use, land and water pollution) than the single-use variants for all but the CVC insertion kits ○ The move to single-use items has not been well studied and appears to be driven by other factors beyond infection control practices, such as cost, ease of use, difficulty making some reusable items patient ready again, individual (doctor) preferences and marketing ○ Pharmaceutical companies have rarely engaged with LCA researchers and published in peer-reviewed journals, perhaps due to concerns regarding commercial confidentiality ○ There is renewed interest in return of unused medicines, one study finding that one-fourth of all returned medicines were suitable for reuse ○ The frequency of dialysis has a greater effect upon CO_2 emissions than dialysis duration; with the rise of home dialysis delivered more frequently, innovative approaches will be required to prevent the predicted doubling of CO_2 emissions per dialysis patient, including methods to reduce consumables and waste disposal • Waste	

		○ Hospitals in the U.S. alone generate an average of 5,500 tons of waste each and every day ○ Avoidance of unnecessary or unproven hospital procedures is likely to have a greater effect than all current hospital recycling initiatives ○ Examination of waste disposal shows financial and environmental benefits stemming from treating infectious waste by microwaving rather than autoclaving, lime or incineration ○ Approximately 30% of all hospital waste is paper/cardboard and a similar proportion is plastic, indicating high recycling potentials ○ Approximately 20% of all hospital waste stems from the OR; the associations of anesthetists and surgeons in the U.K. and Ireland have separately issued policy documents to promote consideration of, and research about, the sustainability of anesthesia and cost-effective and sustainable surgery Source (AMSTAR rating 2/9)	
	• Mitigation and adaptation strategies ○ Energy-use reductions ▪ Building ○ Non-energy emission solutions ▪ Reuse and recycling ○ Decarbonizing the supply chain ▪ Anesthetic gases	• The aim of this systematic review was to assimilate the published studies concerning the sustainability of the perioperative environment, focusing on the impact of implemented interventions, with 34 studies included • Studies were divided into broad themes; recycling and waste management, waste reduction, reuse, reprocessing or life-cycle analysis, energy and resource reduction and anesthetic gases • Over 30% of an entire hospital's waste is generated from surgical provision, of which a significant portion originates from single-use plastic consumables and their associated packaging • Geographical variations in surgical provision can have an impact on the carbon footprint of the same operation, with cataract surgery ranging from six kg CO2eq in India up to 182 kg CO2eq in the U.K. • Recycling and waste reduction ○ Eight studies evaluated interventions that had an impact on recycling and waste management, plus four evaluated waste reduction via streamlining of instrument packs ○ Recycling and waste-reduction interventions can usually be implemented as an extension of national domestic recycling programs ○ Theatre packs were streamlined by reducing the number of rarely used instruments or disposables; this technique led to an annual decrease in waste of 1.48 tons • Reuse, reprocessing or life-cycle analysis ○ Eleven studies evaluated single-use disposables with items evaluated including: laparotomy mops, gowns, drapes, plastic drug trays, scissors, central venous catheter insertion kits and airway management tools	Literature last searched March 2020

		○ Overall, the studies identified that reusable items could lead to a substantial improvement in sustainability, with 70% reduction in waste generation, three-fold lower water consumption, and 2.5-fold lower energy consumption ○ The destruction of PVC plastics through burning results in increased release of carcinogenic compounds from single-use items when compared to reusable ones ○ The use of reusables is only more sustainable if there is the infrastructure to efficiently reprocess the items; for instance, in Australia reuse had monetary benefits but resulted in a 9% increase in emissions compared to the 84% and 48% decreases seen in the U.K. and U.S. respectively; this is due largely to Australia still having 75% of its electricity generated from coal which is a stark contrast to the U.K.'s 1% • Energy reduction and minimizing use of natural resources ○ Each of the nine studies that addressed energy and resource reduction evaluated different interventions including water usage during scrubbing, sterilization processes, and different anesthetic machines energy profiles ○ Hospital sterilizers use 40% of their electricity and 20% of their water whilst idle, and turning off idle machines have shown to save 26% and 13% of a hospital's electricity and water respectively ○ Operating theatre occupancy sensors can result in an electricity saving of one-third • Anesthetic agents ○ Four studies looked to reduce impact of anesthetic; desflurane has been identified as having a greater potential impact on global warming than other agents ○ Three of the studies looked at interventions to reduce desflurane usage with a combination of staff education, lower gas flows and promotion of IV anesthesia leading to a 25–55% decrease in its usage ○ Propofol can be a significant source of drug wastage and the intervention of changing the pharmacy dispensing of propofol from 50- or 100-mL bottles to smaller units reduced wastage by 90.4% Source (AMSTAR rating 6/9)	
	• Mitigation and adaptation strategies ○ Investments using a net-zero approach or requirement ○ Energy-use reductions ▪ Building ▪ Transportation ○ Non-energy emission solutions	• The objective of this review was to synthesize available actions that could limit CO2 emission in the operating room (OR) and their potential benefits upon the environment, whilst preserving quality of care; 38 studies met the inclusion criteria • Six core climate-smart actions were identified: 1) waste reduction by segregation; 2) waste reduction by recycling, reuse, and reprocessing; 3) sterilization; 4) anesthesia gas management; and 5) improvement of energy use • Improve segregation ○ Nine studies reported that improvement of waste reduction in the OR requires better waste management and segregation; there is high GHG emission during the waste destruction process, which may have a significant impact	Literature last searched April 2021

	▪ Industrial-process improvements ▪ Reuse and recycling ○ Decarbonizing the supply chain ▪ Anesthetic gases	○ Waste segregation is the backbone of any climate-smart action in the OR; despite national and local rules for segregation, there is a lack of education to improve and accurately segregate waste ○ A dedicated educational program should be implemented systematically in every institution (or even better, at medical schools) to improve correct segregation and collective awareness of sustainable values • Improve waste reduction and recycling ○ Eleven studies addressed waste recycling and reduction ○ Actions can be oriented to solid waste reduction, OR recyclables and reusables, energy and water reduction, and charitable donations ○ Waste production must be considered all along the patient pathway (before, during, and after the surgery); each one requires different recycling facilities and specific actions ○ Overall, it is important to create educational programs and improve awareness of recycling, and reduce waste production in the OR ○ These actions should be carried out in line with the implementation of dedicated recycling facilities adapted to the patient pathway • Improve reuse and reprocessing ○ Seven studies evaluated reuse of material and equipment ○ Overall, the study found that the implementation of reprocessing of Single Use Medical Devices (SUMDs) as well as reducing their use has an important impact on waste production and consequently on the environment ○ Although SUMDs might have a lot of benefits, clinicians and stakeholders should consider the carbon footprint and should better assess their indication to regulate their use ○ Moreover, manufacturers and institutions should work hand-in-hand, in advance of any contract agreement, to propose dedicated reprocessing pathways to reduce the carbon footprint of waste produced • Sterilization ○ One guideline and five studies evaluating the impact of sterilization ○ In the last decades, hospitals modernized their sterilization process with either ethylene oxide or radiation technologies, opening up the ability to reuse disposables, but data regarding their ecological impact remain weak ○ Efforts to reduce the environmental footprint of reusable items should be directed towards decreasing water and energy consumed in cleaning and sterilization ○ For reusable devices in anesthesiology, washer and H2O2 sterilizer electricity were responsible for, respectively, 86% and 7% of GHG emissions	

		○ A study comparing the carbon footprint between reusable and disposable ureteroscopes has shown that the main CO2e for reusable ureteroscopes were generated by sterilization (3.95 kg of CO2 per case accounting for 88.4% of total CO2 emission), whereas it was mainly caused by the manufacturing of disposable equipment (3.84 kg of CO2 per case accounting for 86.5% of total CO2 emission) ○ A design permitting low-effort cleaning and sterilization for reusable equipment could be a promising lead to reduce sterilization impact; moreover, reducing the number of devices that need sterilization could also be an efficient way to reduce environmental impact and lower economic costs ○ The impact of sterilization and its GHG emissions are poorly assessed and deserve better attention from researchers • Anesthetic gas management ○ Three studies underlined the impact of anesthetic gases on GHG emissions ○ A prospective study involving three different centres from the U.S. and Europe found that anesthetic gases and energy consumption were the largest sources of GHG emissions in the OR ○ Interestingly, the absence of desflurane utilization in the U.K. explains why emissions due to anesthetic gases were 10 times lower in the European department than in the U.S. ○ Despite its fast induction and emergence, desflurane has very high GHG emissions and has been pointed out as the biggest contributor to anesthetic gas emission; for instance, GHG emission of this gas is five-fold higher than that of isoflurane and 20-fold higher than that of sevoflurane ○ Another study found that the removal of desflurane would reduce GHG emissions by 25% during laparoscopic surgery ○ Concerns regarding anesthetic gases should make healthcare workers more careful and propose more alternative anesthetic options such as local, regional, or total intravenous anesthesia after consultation with anesthesiologists • Energy efficiency in the OR ○ Fossil fuel combustion is the dominant source of healthcare climate emissions ○ The use of coal, oil and gas to power hospitals, healthcare-related travel, and manufacture and transport of healthcare products comprises 84% of all healthcare-related climate emissions across facility operations, supply chain, and the broader economy ○ In the OR, heating, ventilation, and air conditioning (HVAC) thermal energy systems comprised 90–99% of overall energy use; this is nearly twice the consumption of other inpatient healthcare facilities	

		○ The study underlined that occupancy-based ventilation strategies reduced unnecessary airflow to unused space and had the potential for considerable energy saving ○ They calculated that by reducing airflow rates overnight and on weekends, keeping only three of 22 theatres online for emergencies, there was a 50% reduction in HVAC energy consumption ○ A pilot study evaluated a radiofrequency identification system that automatically turned on and adjusted itself according to the number of persons in the OR; the study indicated that the system was working correctly in 98–99% of the cases and could generate 50% energy saving ○ Health Care Without Harms in collaboration with ARUP – an independent firm working across every aspect of today's built environment – is a global road map for healthcare decarbonization, including:power the OR with 100% clean, renewable electricity; invest in zero-emission infrastructure; and transition to zero emission, and sustainable travel and transport by encouraging active travel and public transport for patients and staff wherever feasible ○ Energy consumption is the highest source of GHGs in the OR, but it is also the one where surgeons and the surgical staff have less impact; stakeholders and institution directors must be encouraged to invest in the construction of a sustainable OR Source (AMSTAR rating 6/9)	
	• Mitigation and adaptation strategies ○ Energy-use reductions ▪ Transportation	• This review investigated greenhouse gas emissions related to telemedicine, its potential role in achieving carbon neutrality and its role in determining policy; 31 studies were included (over 57,000 patients) • Few results report the carbon burden associated with telemedicine itself, however, of those that do, this still resulted in a greater than 95% reduction even by the most conservative estimates • Carbon savings ranged from 0.69 kg CO2e (carbon dioxide equivalent) to 893 kg CO2e per encounter • Distances saved also ranged from 6.1 to 3,386 km • Further analysis of 18 included studies was conducted for cost savings that ranged from 1.73 euros in fuel costs to over US$900 in travel related expenses • Of the studies that examined the carbon burden, the majority only investigated the running of the equipment; however, one study evaluated the potential life-cycle emissions of the telemedicine equipment arriving at an upper limit of 8.43 kg CO2e • Comparison of life-cycle emissions would result in more accurate data sets Source (AMSTAR rating 4/9)	Literature last searched December 2021

	• Mitigation and adaptation strategies ○ Investments using a net-zero approach or requirement	• A short-cut systematic review was carried out to establish if strategies to reduce greenhouse gas emissions in the emergency department could succeed while maintaining comparable care standards • Of ,2914 papers found in the searches, 40 were selected for full-text review and none of them contained any data or observation of an impact made either clinically or environmentally by an intervention made in an emergency department with the intention of reducing greenhouse gas emissions Source (AMSTAR rating 3/9)	Literature last searched January 2020

Scoping review	• Mitigation and adaptation strategies
	  ○ Energy-use reductions
	  ▪ Building
	  ○ Non-energy emission solutions
	  ▪ Reuse and recycling
		• This review aimed to synthesize evidence on the carbon footprint of commonly used infection-prevention measures in the OR, namely medical devices and instruments, surgical attire, and air treatment systems; 57 articles were included
		• Many infection-prevention measures result in increased emissions
		• The use of disposable items instead of reusable items generally increases the carbon footprint, depending on sources of electricity
		• Controversy exists regarding the correlation between air treatment systems, contamination and the incidence of surgical site infections (SSIs)
		• Evidence suggests that new air treatment systems consume more energy and do not necessarily reduce SSIs compared with conventional systems
		• Medical devices and instruments
		  ○ Instruments that are going to be reused require mechanical cleaning before decontamination; high-level disinfection is not enough
		  ○ The most effective solution to sterilization problems is the use of disposable instruments; this increased waste production and the use of natural resources
		  ○ U.S. Food and Drug Administration commissions and the U.S. Government Accounting Office have not found evidence to support the opinion that single-use devices reprocessed under approved conditions (including disinfection, cleaning, testing and sterilization) resulted in elevated health risks for patients, although 28% of physicians believe that this would be the case
		  ○ The direct economic savings to hospitals have been estimated to be approximately US$20,000 per operating room annually
		  ○ Strict regulations (Medical Device Regulations) are a barrier to the reprocessing of single-use devices
		• Surgical attire
		  ○ Six studies concluded that reusable textiles had substantially better environmental profiles than disposable textiles
		  ○ The use of disposable textiles increased the energy use and carbon footprint by 200–300%
			Literature last searched June 2021

		○ An LCA estimated that choosing reusable surgical gowns over disposable gowns reduced energy consumption by 64% and the carbon footprint by 66% ○ Regarding the use of isolation gowns hospital-wide, the carbon footprint was reduced by almost 30% when reusable gowns were used ○ The US Centers for Disease Control and Prevention (CDC) concluded that there are no data suggesting important differences between reusable and disposable gowns and drapes in terms of the prevention of SSIs ○ The use of reusable footwear, surgical gowns and laundered hats will reduce the volume of disposable gowns, caps and overshoes • Heating, ventilating and air conditioning systems ○ Energy conservation efforts should focus on HVAC system management; heating and air conditioning requirements mainly depend on the hospital's geolocation and ambient temperature ○ For instance, one study compared the energy consumption of OR HVAC systems under the different weather conditions in Toronto, Calgary and Sacramento, and found that the use of electricity for cooling was nearly five times higher in Sacramento, while the use of gas for heating was significantly higher in Calgary ○ One way to reduce the environmental impact of the OR is switching off or reducing the HVAC system when the OR is not in use (setbacks), for instance at night or on weekends ○ When the air treatment in ORs is switched off completely for 10 hours, acceptable levels of airborne particles and bacteria are reached within 30 minutes after restarting the system, and this can result in energy savings up to 70% ○ When an OR is not in use, reducing air changes per hour could be a beneficial focus for reducing the carbon footprint; in addition, hospitals could save $2,585 per OR per year and $33,600 per year attributable to OR setbacks of the HVAC ○ Radio-frequency identification (RFID) technology is an automatic identification and data capture technology that can be used to offer unique medical staff and patient identification, and react with the HVAC system to reduce energy consumption in the OR ○ A pilot program conducted in Taiwan shows that the RFID system could operate much more efficiently with an estimated 50% reduction in energy consumption compared with the normal ventilation system ○ An advantage of this system is when the OR is needed in an acute setting, the system will start automatically when the first medical staff enters the OR; this way, the indoor air quality of the OR will automatically be ready for surgery to take place Source (AMSTAR rating 3/9)	

Protocols for reviews that are already underway	• Mitigation and adaptation strategies	• This scoping review was planned to summarize the current knowledge about hospital climate action and existing tools to measure progress in this area • This review was planned to include mitigation and adaptation measures, efforts to enhance the adaptive capacity in specific areas, promoting institutional improvement, embracing adaptive management and developing tools Source	Protocol published December 2019
Single studies	• Mitigation and adaptation strategies o Investments using a net-zero approach or requirement o Non-energy emission solutions ▪ Reuse and recycling	• In Canada, the healthcare sector is responsible for about 4.6% of the nation's total GHG emissions and an estimated 200,000 tons of other harmful pollutants; it has been estimated that these emissions result in 23,000 disability-adjusted life years lost annually • This documentary analysis was used to investigate the workplace policies that indicated how employees should engage with environmentally responsible practice; the study took place in one large Western Canadian healthcare organization • The major themes from this study relate to the resource life-cycle stages: procurement of resources, resource utilization, resource conservation, and waste management • The study found that in all the life-cycle stages, the concerns for safety were important determinants of decisions • For instance, those in charge of the procurement process are encouraged to find vendors who offer fiscally responsible contracts that deliver safe and effective goods, from what is written in the policies; the procurement process does not seem to consider the emissions produced by the supply chain or if there are other alternative resource sources that have a lower environmental and climate impact • Health professionals can lead "green teams" in their places of work, which aim to reduce waste and GHG emissions, and they can work with the public to help convey important climate health information and promote planetary health among patients and families • Safety concerns were also important in determining actions and behaviours about the use of personal protective equipment and the management of waste • Procurement o The study did not find current considerations for planetary health within the policies related to the procurement of resources o However, the study highlighted an opportunity: healthcare organizations can use market values and purchasing rules to encourage manufacturers and vendors to produce and sell resources that are safe and environmentally clean; a healthcare organization can simultaneously reduce its GHG emissions and environmental impact, and encourage more manufacturers and vendors to develop innovation in this field • Resource utilization and conservation	Literature last searched March 2020

		○ Organizational policies that discussed the utilization or conservation of healthcare resources did not mention the climate or environmental impact of these activities ○ Organization could direct employees to reduce unnecessary resource consumption and promote resource conservation whenever possible; this includes outlining appropriate utilization of both workplace supplies and resources such as electricity or thermal power • Waste management ○ These policies were the only ones that explicitly prioritized the reduction of healthcare's environmental impact ○ Specifically, these policies aimed to reduce the potential for toxic chemical spills or other scenarios where possible environmental contamination could occur ○ Policies in this approach could encourage the reduction of waste produced in the first place, the assessment and monitoring of organizational waste, and even GHG emissions ○ The study highlighted that one strength of the healthcare sector is its expertise in utilizing monitoring systems, assessments, and tracking methods Source	
	• Mitigation and adaptation strategies ○ Decarbonizing the supply chain ▪ Anesthetic gases	• This quality-improvement study assessed and evaluated the impact of sustainability interventions on the environmental and financial cost of inhaled anesthetic gas use to guide future initiatives and research in reducing carbon emissions from healthcare practice in the Royal Brisbane and Women's Hospital • Quality-improvement interventions were implemented and overseen by the department director and staff specialists, and no formal staff training was required • Interventions included staff education of desflurane-sparing practices, distribution of posters, and progressive removal of desflurane from operating rooms • Researchers obtained information about usage (bottles) and expenditure for desflurane and sevoflurane from January 2016 to December 2021 • The total number of bottles of sevoflurane and desflurane purchased from January 2016 to December 2021 decreased by 34.76% (from 1,991 to 1,299 bottles), the number of desflurane bottles purchased decreased by 95.63% (from 800 to 35 bottles), and the number of sevoflurane bottles purchased increased by 6.13% (from 1,191 to 1,264 bottles) • Combined desflurane and sevoflurane emissions decreased by 87.88% • In 2016, desflurane made up 92.39% of the annual CO2e, which steadily decreased to 33.36% in 2021 • Combined sevoflurane and desflurane usage costs decreased by 58.33%	Published August 2022

		• Applying desflurane-sparing practice can heavily limit anesthetic drug expenditure and contribution to environmental waste Source	

	• Mitigation and adaptation strategies
	  ○ Energy-use reductions
	  ▪ Building
	  ▪ Transportation
	  ○ Low- or zero-carbon electricity supply
	  ▪ Renewable energy
	  ○ Electrification and other fuel switching
	  ▪ Appliances
	  ▪ Vehicles
	  ○ Non-energy emission solutions
		• This study focused on the carbon footprint of the stationary emission sources of a hospital in Athens, Greece
		• This study served as a second step in the development of an action plan for the mitigation of greenhouse gas emissions in the hospital-based healthcare of the Hellenic (Greek) Army
		• A portfolio of energy-saving and emission-reduction actions is proposed and mapped according to their abatement cost and greenhouse gas reduction potential
		• The highest decrease of GHG emissions is expected to be materialized by the decarbonization of the Greek power sector, the replacement of face-to-face hospital visits by telemedicine, primarily by reducing transport-associated emissions
		• Electricity
		  ○ Electrification can reduce the hospital's GHG emissions soon, depending on the resources used by the Greek electrical grid operators
		  ○ The increase of renewable energy sources and gas-fired plants, and the shutting down of lignite-fired power plants in the country by 2028 will have a positive impact on reducing indirect GHG emissions in all economic sectors, including the healthcare sector
		  ○ Other low-cost actions such as the "turn the thermostats down and light switches off" policy with posters up in the staff areas and stickers above windows, light switches, air conditioning, and electricity-consuming medical equipment can lead to important energy savings and persuade the employees to participate and be environmentally conscious
		• Transport
		  ○ The study proposed development and broader use of telemedicine, which could play a critical role in the transition to a net carbon-zero healthcare sector
		  ○ Setting limitations or banning free parking inside the hospital premises, providing incentives for the use of public transport and other more "active" means of transport, such as walking or cycling, and training on eco-driving
		• Ambulances
		  ○ Use of biofuels in ambulances
		• Air conditioning systems and refrigerators
		  ○ Gradual replacement of stationary air conditioning systems and freezers with appliances that are more energy efficient
		• Buildings
			Published February 2022

		○ Hospital buildings should maintain appropriate internal temperatures in areas with different temperature needs, such as in emergency rooms and clinics, in contrast with the waiting rooms and the administration offices ○ The energy team of the hospital should make a chart showing the desired temperatures for each area in the hospital, from the lowest to the top floors of the building ○ Minimize losses by using automatic doors in frequently used hospital entrances. Source	
	• Mitigation and adaptation strategies ○ Investments using a net-zero approach or requirement	• This study aimed to evaluate the extent to which organizational factors facilitate or inhibit the implementation of the National Health Service (NHS) carbon-reduction strategy within acute hospital settings • The 'NHS carbon reduction strategy' was developed in England in 2009, which requiresNHS organizations to develop a local carbon-reduction strategy (the Sustainable Development Management Plan) that details different carbon-reduction measures • The study found that carbon-reduction measures were most likely to be implemented if the Trust Board was sufficiently pressured by staff and reputational fears, and the potential impacts of these measures were perceived to align with wider organizational aims • Differences in implementation of carbon-reduction measures across hospital sites were related to logistical factors, accessibility to regional partners and contractual relationships • There were expected carbon, energy and long-term financial savings, with variability in the effectiveness of some carbon-reduction measures post implementation • Carbon-reduction measures which were perceived to possess greater co-benefits were more likely to be implemented, with the majority of those implemented belonging to energy, travel and procurement, that is, those mostly associated with external funding and/or partner organizations Source	Published September 2021
	• Mitigation and adaptation strategies ○ Energy-use reductions ▪ Transportation ○ Non-energy emission solutions ▪ Industrial-process improvements	• This study aims to quantify the average carbon footprint of a primary-care consultation through a life-cycle assessment, describe differences between primary-care practices (best, worst and average performing) in western Switzerland, and identify opportunities for mitigation • The study defined an average practice as consisting of two full-time physicians and two full-time practice assistants, working in a 207-m2 premises; together, it provides 6,273 consultations per year, equivalent to 27 consultations per day (considering time off and holidays of staff)	Published January 2022

		• The study found that an average medical consultation generated 4.8 kg of CO_2eq, and overall an average practice produced 30 tons of CO_2eq per year, with 45.7% for staff and patient transport and 29.8% for heating • Medical consumables produced 5.5% of CO_2eq emissions, while in-house laboratory and X-rays contributed less than 1% each • Mitigation of a practice's carbon footprint is grounded primarily in transport organization; a dense and local network of primary-care practices could decrease the length of the journey a patient needs to make to see his or her doctor and encourage her or him to come by foot • An effective network of public transportation could prompt staff to commute to work rather than use their cars • Telehealth could be investigated as a carbon-mitigation option, to cut down on transportation (patient and staff) Source	
	• Nature and scale of health-system emissions	• This study aimed to measure the carbon footprint of Australia's healthcare system through an observational economic input–output life-cycle assessment • In 2014–15 Australia spent $161.6 billion on healthcare that led to CO_2e emissions of about 35.772 (68% CI 25 398–46.146) kilotonnes, which represents 7% of all Australian emissions • The most important emitter sectors within the healthcare were public and private hospitals (44%), pharmaceuticals (18%), and capital expenditure for buildings (8%) • All other healthcare sectors contributed a further 30% of the total carbon footprint, among them, community or public health (6%), general practice (4%), dentistry (3%), aids and appliances (3%), other health practitioners (2%), research (2%), administration (2%), and patient transport services (1%) Source	Published January 2018

	• Mitigation and adaptation strategies
	  ○ Electrification and other fuel switching
	  ▪ Vehicles
		• The electrification of the transportation sector is seen as a main pathway to reduce CO_2 emissions and mitigate the earth's climate change
		• Electric vehicles are entering the market fast; however, they have not been used as ambulances yet; the transition to the new type of vehicle is a matter of time
		• Based in artificial intelligence, this study proposed a framework for developing online algorithms that schedule the charging of electric ambulances and their assignment to patients
		• The study concluded that for the electric ambulances to become a reality, apart from the advancements in the engineering domain, the development of fast and efficient online scheduling algorithms accompanied with machine-learning algorithms able to accurately
			Published May 2022

		predict future demand and supply is a key point to achieve a gradual transition from conventional ambulances to electric ones Source	

	• Mitigation and adaptation strategies
	  ○ Non-energy emission solutions
	  ▪ Industrial-process improvements
	  ○ Decarbonizing the supply chain
	  ▪ Anesthetic gases
		• Public Health England (PHE) commissioned a calculation and analysis of the carbon footprint of key dental procedures
		• The carbon footprint of the NHS dental service is 675 kilotonnes carbon dioxide equivalents (CO2e)
		• Examinations contributed the highest proportion to this footprint (27.1%) followed by scale and polish (13.4%) and amalgam/composite restorations (19.3%)
		• Items with a low individual carbon footprint are radiographs, fluoride varnish and fissure sealants
		• The higher carbon footprints come from more intensive procedures, or procedures that require more than one visit such as crowns or dentures
		• The fictitious example of a patient receiving nitrous oxide by itself would amount to the highest per item carbon footprint of 119kgCO2e; the concern with nitrous oxide is that it is a toxic greenhouse gas with a high global warming potential; reducing the use of nitrous oxide would be beneficial for the environment, but managing patients with nitrous oxide is often the only alternative to intravenous sedation or general anesthetic, both of which have a higher carbon footprint than nitrous oxide
		• From an emissions perspective, nearly two-thirds (64.5%) of emissions related to travel (staff and patient travel), 19% procurement (the products and services dental clinics buy) and 15.3% related to energy use
		Source
			Published October 2017

	• Nature and scale of health-system emissions	• This study estimated the extent of Canadian healthcare-associated life-cycle emissions as well as the public-health damages they cause, both directly from facility and vehicle emissions and indirectly through the purchase of emissions-intensive goods and services • The study used a linked economic-environmental-epidemiological modelling framework to quantify pollutant emissions and their implications for public health, based on Canadian national healthcare expenditures over the period 2009–15 • The study found that on a life-cycle basis, Canada's healthcare system was responsible for 33 million tonnes of carbon dioxide equivalents (CO2e), or 4.6% of the national total, as well as >200,000 tonnes of other pollutants • These emissions might represent a median estimate of 23,000 disability-adjusted life years (DALYs) lost annually from direct exposures to hazardous pollutants and from environmental changes caused by pollution; hospitals and prescribed drugs each contribute nearly a quarter of total health damages	Published July 2018

		• This study corroborated similar estimates for the United Kingdom, Australia, and the United States, with emissions from hospitals and pharmaceuticals being the most significant expenditure categories • In both Canada and the U.S., the largest contributing economic sector to healthcare GHG emissions is electricity generation, transmission and distribution; one important reason for the relative difference in healthcare life-cycle GHG emissions between the two countries is that electricity generation in Canada is less carbon intensive than in the U.S. Source	
	• Nature and scale of health-system emissions	• This Special Report summarizes several initiatives and compares three toolkits for implementing sustainability and resiliency measures for healthcare facilities: the Canadian Health Care Facility Climate Change Resiliency Toolkit; the U.S. Sustainable and Climate Resilient Health Care Facilities Toolkit; and the PAHO SMART Hospitals Toolkit of the World Health Organization/Pan American Health Organization • Canada o The Canadian Coalition for Green Health Care, with support from Health Canada and the Nova Scotia Department of Environment, developed the "Health Care Facility Climate Change Resiliency Toolkit" o Six facilities in Nova Scotia, Ontario and Manitoba have piloted the toolkit; the first facility was the University Health Network (Toronto, Canada) o It is expected this toolkit can help the health sector in Canada plan for the challenges posed by climate change; the facilities that have used the toolkit have become important agents of change for reducing fossil fuel emissions, improving resiliency to extreme weather events, and advocating for public understanding of climate change and health • The U.S. o The "U.S. Sustainable and Climate Resilient Health Care Facilities Toolkit" was created as an initial component of the 2013 President's Climate Action Plan and the "Enhancing Health Care Resilience for a Changing Climate" effort o This toolkit helps health sector officials prepare for climate change impacts based on five elements: climate risks and community vulnerability assessments; land use, building design, and regulatory context; infrastructure protection and resiliency planning; essential clinical care service delivery; and environmental protection and ecosystem adaptation • PAHO SMART Hospitals Toolkit o In addition to a Hospital Safety Index (HIS), the Toolkit contains a Baseline Assessment Tool, a Green Checklist, a Cost Benefit Analysis Tool, and a Sustainability Construction Guide Annex	Published September 2016

		○ In Phase 1 of the project, the pilot facilities – Georgetown Hospital (St. Vincent and the Grenadines) and Pogson Hospital (St. Kitts) – applied the toolkit and retrofitted their facilities with success; they achieved a 50%+ reduction in electrical power consumption and an increase in patients' use of the facilities Source	
	• Mitigation and adaptation strategies ○ Energy-use reductions ▪ Transportation	• Outreach clinics may represent tools to assist healthcare systems to decrease greenhouse gas emissions by optimizing patient-related travel, and this study sought to estimate the carbon footprint savings associated with a head and neck surgery outreach clinic • This study was a cross-sectional survey of patient travel patterns to a surgical outreach clinic compared to a regional cancer treatment centre from December 2019 to February 2020; 113 patients were included for analysis • The study found that most patients (85.8%) used their own personal vehicle to travel to the outreach clinic • The median distance to the clinic and regional centre were 29 km (IQR 6.0–51.9) and 327 km (IQR 309.0–337.0) respectively • The mean carbon-emission reduction per person was therefore 117,495.4 g (SD: 29,040.0) to 143,570.9 g (SD: 40,236.0); this represents up to 2.5% of an average individual's yearly carbon footprint • There is a substantial carbon footprint related to traveling to healthcare appointments, and this study has shown carbon emissions may be reduced by providing outreach clinics when healthcare is regionalized Source	Published April 2021
	• Mitigation and adaptation strategies ○ Decarbonizing the supply chain ▪ Low-carbon inhalers	• As part of the CARBON program, the SABA CARBON Europe and Canada observational cohort study quantified the carbon footprint associated with the use of both reliever and controller inhalers in 20 European countries and in Canada, and short-acting β2-agonists (SABAs) overuse (prescription/dispensing of three or more canisters per year) in five European countries and two Canadian provinces (Alberta and Nova Scotia) from the SABINA program • Overall, the study found that suboptimal respiratory treatment, in the form of high SABAs use across Europe and Canada, remains widespread, representing approximately two-thirds of total GHG emissions • Authors suggested that these findings highlight the importance of assessing the contribution of SABAs to the carbon footprint of respiratory treatment, which in many countries were commonly used and administered by metered-dose inhalers, thereby explaining higher GHG emissions associated with SABA versus controller inhaler use Source	Published August 2022

	• Mitigation and adaptation strategies
	  ○ Electrification and other fuel switching
	  ▪ Vehicles
		• This was a two-phase study of operational and financial data from a convenience sample of Australian ambulance operations to inventory their energy consumption and greenhouse gas emissions for one year; state- and territory-based ambulance systems serving 58% of Australia's population and performing 59% of Australia's ambulance responses provided data for the study
		• The study found that emissions for the participating systems totalled 67.390 metric tons of carbon dioxide equivalents
		  ○ For ground ambulance operations, emissions averaged 22 kg of carbon dioxide equivalents per ambulance response, 30 kg of carbon dioxide equivalents per patient transport and 3 kg of carbon dioxide equivalents per capita
		  ○ Vehicle fuels accounted for 58% of the emissions from ground ambulance operations, with the remainder primarily attributable to electricity consumption
		  ○ Emissions from air ambulance transport were nearly 200 times those for ground ambulance transport
		• Potential strategies for reducing ambulance-system energy consumption and GHG emissions include reducing unnecessary ambulance responses and ambulance transports, developing flexible response time policies, reducing driving speeds when transporting stable patients without life-threatening conditions, reduced ambulance idling at emergency scenes and receiving hospitals, the use of hybrid vehicles for administrative and support vehicle fleets, or the use of bio-diesel for ambulances
		• However, none of these proposed strategies has been empirically evaluated; their actual impact on energy consumption and emissions, as well as patient outcomes, remains to be determined
		Source
			Published August 2012

	• Mitigation and adaptation strategies
	  ○ Decarbonizing the supply chain
	  ▪ Food, catering and nutrition
		• This study presents a comprehensive characterization of plate waste (food served but not eaten) at an acute-care hospital in Portugal, and elaborates on possible waste-reduction measures
		• The study reported that on average each patient throws away 953 g of food each day, representing 35% of the food served; this equates to 8.7 thousand tonnes of food waste being thrown away each year at hospitals across Portugal
		  ○ These tonnes of food transformed into waste represent economic losses and environmental impacts, being estimated that 16.4 thousand tonnes of CO2 (equivalent) and 35.3 million euros are the annual national indicators in Portugal
		  ○ This means that 0.5% of the Portuguese National Health budget gets thrown away as food waste
		• Given the magnitude of the food problem five measures were suggested to reduce food waste:
			Published December 2015

		○ Bread on demand ○ Switching from a plated to a bulk system for meal delivery ○ Choice of portion size ○ Increase menu options ○ Prompt update of empty beds to detect and record last-minute changes to the number of meals required Source	
	• Mitigation and adaptation strategies ○ Non-energy emission solutions ▪ Industrial-process improvements	• This article focused on the emissions of pharmaceuticals, since the carbon of pharmaceuticals are relatively understudied despite the fact that globally, the pharmaceutical industry's carbon emissions are more than 50% higher than the automotive sector • In the U.K. (2007) it was estimated that pharmaceuticals contribute nearly a quarter of the CO2 emitted each year by the health sector (2007); in the U.S. (2009) it was estimated as 14% • Factors that contribute to pharmaceutical carbon emissions include over prescription, pharmaceutical waste, antibiotic resistance, routine prescriptions, non-adherence, drug dependency, lifestyle prescriptions, and drugs given due to a lack of preventive healthcare • Greening' the life cycle of pharmaceuticals requires the support of chemists, medical engineers, medical manufacturers, product designers, and other supportive stakeholders • Carbon reduction of pharmaceuticals can lead to cleaner, more sustainable healthcare Source	Published April 2021
	• Mitigation and adaptation strategies ○ Non-energy emission solutions ▪ Industrial-process improvements	• This study performed a prospective life-cycle assessment at two Australian university-affiliated health services of five imaging modalities: chest X-ray (CXR), mobile chest X-ray (MCXR), computerized tomography (CT), magnetic resonance imaging (MRI) and ultrasound (US) • The study found a mean CO2e emissions of 17.5 kg/scan for MRI; 9.2 kg/scan for CT; 0.8 kg/scan for CXR; 0.5 kg/scan for MCXR; and 0.5 kg/scan for US • Authors recommend that clinicians and administrators reduce carbon emissions from diagnostic imaging by: ○ Reducing the ordering of unnecessary imaging ○ When clinically appropriate, ordering low-impact imaging (X-ray and US) instead of MRI and CT ○ Whenever possible, scanners should be turned off to reduce emissions from standby power ○ Ensuring high utilization rates for scanners reducing standby times Source	Published July 2022

	• Mitigation and adaptation strategies
	  ○ Decarbonizing the supply chain
	  ▪ Low-carbon inhalers
		• This article presented indicators of the carbon footprint, European and Polish legal regulations on the reduction of greenhouse gases, a short review of inhalers and inhalation drugs based on the example of the Polish market, results of studies on the carbon footprint of selected inhalers, and methods of reducing the negative impact of inhalers on the environment
		• Methods of reducing the carbon footprint of inhalers:
		  ○ Reducing the use of short acting beta-2 agonist (SABA) "on demand" in all types of inhalers by improving asthma and COPD control (physician, patient)
		  ○ Optimal use of the inhalation chamber, usually associated with the improvement of the clinical efficacy of pressurized metered-dose inhaler (pMDI) drugs (physician, patient)
		  ○ Using inhalers for the last dose and not wasting doses by releasing the drug into the atmosphere (patient)
		  ○ Introduction of pMDI with new propellants with lower global warming potential (GWP) values, for example, hydrofluoroalkane (HFA) 152a (manufacturer, payer, physician)
		  ○ Rational replacement of pMDI by dry-powder inhaler (DPI) or metered-dose liquid inhaler MDLI (doctor)
		  ○ Reducing the number of inhalers in each patient through the wider use of drugs combined in one inhaler and the introduction of new two- or three-component formulations (manufacturer, physician, payer)
		  ○ Creating DPI and MDLI inhalers with replaceable cartridges extending the time of using the inhaler (manufacturer)
		  ○ Using DPI capsule for a larger number of doses, which requires actions that improve the inhalers (manufacturer)
		  ○ Promoting the recycling of all inhalers (manufacturer, pharmacy, patient)
		Source
			Published in 2021

Appendix 3: Medium and low relevance evidence documents included but not profiled in the summary

Hyperlinked document title
Climate change and eHealth: a promising strategy for health sector mitigation and adaptation
Health care's response to climate change: a carbon footprint assessment of the NHS in England
Estimated Global Disease Burden From US Health Care Sector Greenhouse Gas Emissions
The Nurses Climate Challenge: A National Campaign to Engage 5,000 Health Professionals Around Climate Change
Manieren om de CO2-voetafdruk van de OK te verlagen [Steps for reducing the carbon footprint of the operating room]
Neue Herausforderungen für die Anästhesie durch den Klimawandel [New challenges for anesthesia due to the climate change]
Education for the Anthropocene: Planetary health, sustainable health care, and the health workforce
Climate change in healthcare: Exploring the potential role of inhaler prescribing
Physicians' responsibility toward environmental degradation and climate change: A position paper of the European Federation of Internal Medicine
Carbon emission savings and short-term health care impacts from telemedicine: An evaluation in epilepsy
Carbon footprint of telemedicine solutions--unexplored opportunity for reducing carbon emissions in the health sector
Carbon Emissions from Overuse of U.S. Health Care: Medical and Ethical Problems
Initiatives to broaden safety concerns in anaesthetic practice: The green operating room
Education for sustainable health care: From learning to professional practice
Inhaled Anesthetics: Environmental Role, Occupational Risk, and Clinical Use
Climate Change and Healthcare: A Complicated Relationship
The global temperature-related mortality impact of earlier decarbonization for the Australian health sector and economy: A modelling study
It's Time for Medical Schools to Introduce Climate Change Into Their Curricula
Sustainable global health practice: An ethical imperative?
The carbon footprint of cataract surgery
Environmental Sustainability in the Cardiac Catheter Laboratory
The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study
Driving down embedded emissions from medical nitrous oxide
The carbon footprint of a renal service in the United Kingdom
A Survey of the American Society of Anesthesiologists Regarding Environmental Attitudes, Knowledge, and Organization
Comparison of the carbon footprint of different patient diets in a Spanish hospital
The carbon footprints of home and in- center maintenance hemodialysis in the United Kingdom
Carbon footprint of inhalational and total intravenous anaesthesia for paediatric anaesthesia: a modelling study
Sustainability in the Operating Room: Reducing Our Impact on the Planet
The Climate-Smart Emergency Department: A Primer
Inhaled Anesthetics: Environmental Role, Occupational Risk, and Clinical Use
Attitude of US obstetricians and gynaecologists to global warming and medical waste

Health care and the environment: local champions, global impact
Reducing critical care's carbon footprint with financial and social co-benefits
Carbon footprint and cost-effectiveness of cataract surgery
The impact on life cycle carbon footprint of converting from disposable to reusable sharps containers in a large US hospital geographically distant from manufacturing and processing facilities
Huella de carbono en el Hospital Base de Puerto Montt [Measurement of the carbon footprint at a regional hospital]
Virtual Residency Interviews Reduce Cost and Carbon Emissions
Carbon footprint of robotically-assisted laparoscopy, laparoscopy and laparotomy: a comparison
Association Between Anesthesia Provider Education and Carbon Footprint Related to the Use of Inhaled Halogenated Anesthetics
The carbon footprints of home and in-center peritoneal dialysis in China
A Practical Guide for Physicians and Health Care Workers to Reduce Their Carbon Footprint in Daily Clinical Work
Reducing health care's carbon footprint--the power of nursing
Nurses and Climate Action
Seasonal variation of air quality in hospitals with indoor-outdoor correlations
Climate change and eHealth: a promising strategy for health sector mitigation and adaptation
Health care's response to climate change: a carbon footprint assessment of the NHS in England
Estimated Global Disease Burden From US Health Care Sector Greenhouse Gas Emissions
The Nurses Climate Challenge: A National Campaign to Engage 5,000 Health Professionals Around Climate Change