ENVIRONMENTAL SUSTAINABILITY IN RADIOLOGY

Why • The Case for Change
What • The Tools for Change
How • The Strategy for Change

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Canada

CASCADES

Canadian Association of Radiologists
L'Association canadienne des radiologistes

NAVIGATION

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INTRODUCTION

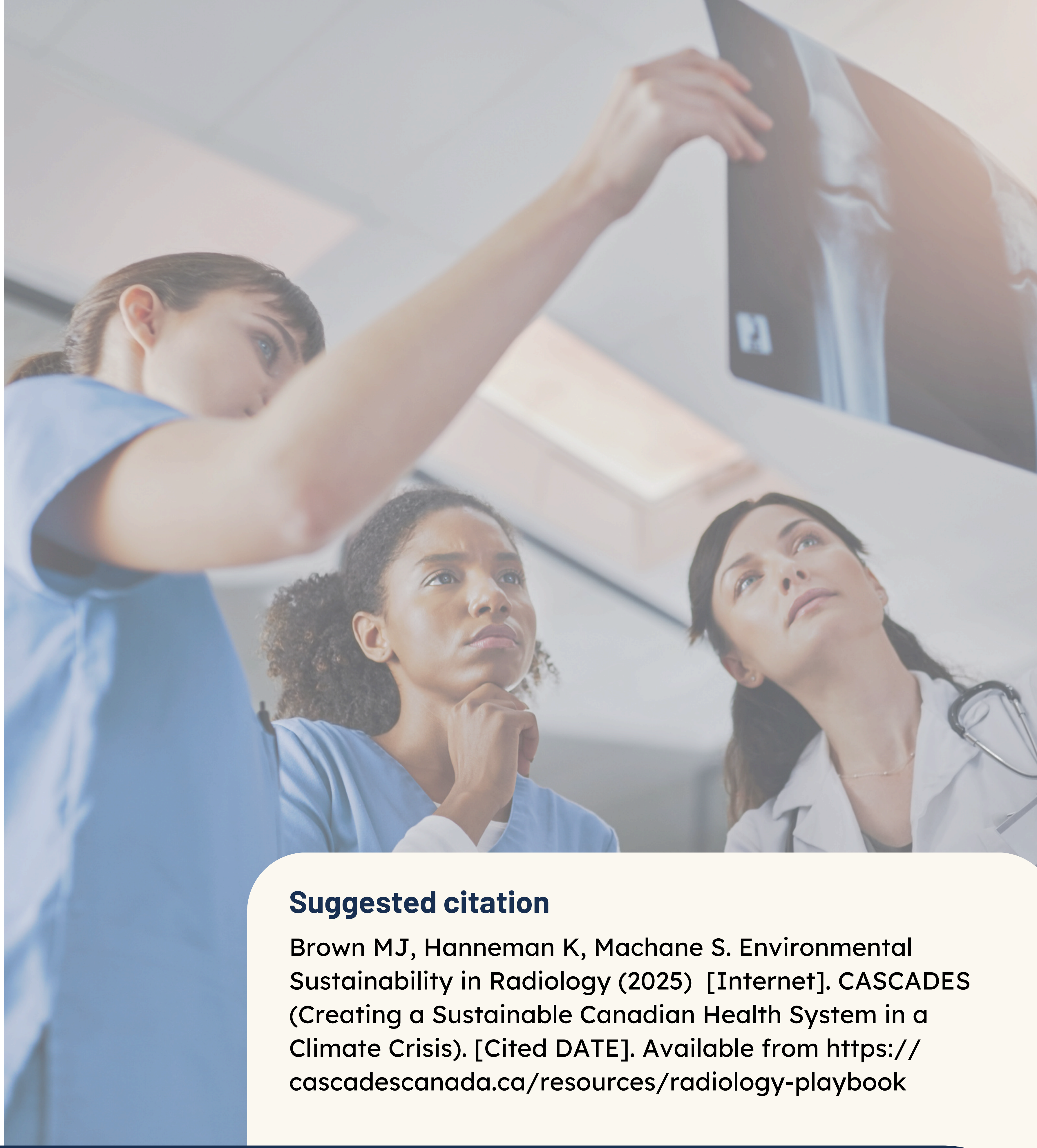
CASCADES develops playbooks as step-by-step guides to implementing well-evidenced change ideas for high-quality, low-carbon, sustainable and/or climate-resilient healthcare and health systems.

This playbook is intended for all medical imaging professionals and teams including radiologists, technologists, healthcare executives, facility operations teams, allied healthcare providers, patients, and industry partners

Specific objectives include:

- Discuss greenhouse gas emissions and waste arising from medical imaging
- Define and describe mitigation and adaption opportunities in radiology in Canada
- Explore strategies for low carbon, high quality medical imaging with estimated impacts

This document was inspired by and modeled after the Canadian Association of Radiologists Statement on Environmental Sustainability in Medical Imaging.



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PLAYBOOK STRUCTURE

WHY
The Case for Change

WHAT
The Tools for Change

HOW
The Strategy for Change

WHY

The Case for Change

1. Triple Planetary Crisis
2. Climate Change Impacts on Health
3. Climate Change and Health Equity
4. Healthcare's contribution to GHG emissions
5. Climate Change and Radiology

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Triple Planetary Crisis

The global population is currently facing three interrelated human caused issues: air pollution, biodiversity loss and climate change (1).

Health systems are significant contributors to climate change, producing an estimated 5% of global greenhouse gas (GHG) emissions (2). Canada's healthcare sector, which emits approximately 4.6% of national GHGs, is no exception (3). The sector tasked with protecting human health is paradoxically contributing to changes in weather patterns as well as air pollution and biodiversity loss. Medical imaging is a resource and energy-intensive component of healthcare, accounting for up to 0.8-1% of global emissions (4). The operation of diagnostic imaging equipment, data storage and access to medical imaging services faces increasing vulnerability to extreme weather events, which could impair the health system's ability to deliver patient care. In the Canadian context, the pursuit of environmentally sustainable medical imaging must consider the unique challenges posed by the country's vast geography, particularly in ensuring access for rural and remote communities.

Air Pollution

Air pollution is the largest cause of disease and premature death in the world, with seven million deaths per year attributable to air pollution (5).

Biodiversity Loss

Anthropogenic biodiversity loss is the decline or disappearance of plants, animals and ecosystems due to human activities such as habitat destruction, pollution, & over-exploitation of resources

Climate change

Mainly driven by human activities, climate change is long-term shifts in temperature and weather patterns which impact life-supporting ecosystems on our planet.

RESOURCES:

- What is the Triple Planetary Crisis? United Nations Framework Convention on Climatre Change
- The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action, Romanello M, et al. (2024)

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Climate Change Impacts on Health

DIRECT IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH

Climate related extreme weather events and changing patters of disease cause direct adverse impacts on human health. According to the World Health Organization, climate-related costs to health are estimated $2-4 billion US per year by 2030 (6). Between 2023 and 2050, climate change is expected to cause 250,000 additional deaths per year from malnutrition, malaria, diarrhea and heat stress alone (7). Direct impacts on human health include examples:

- Extreme weather events including storms, floods, hurricanes, extreme heat events
- Poor air quality due to wildfires and air pollution
- Changing patterns of vector borne disease

INDIRECT IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH

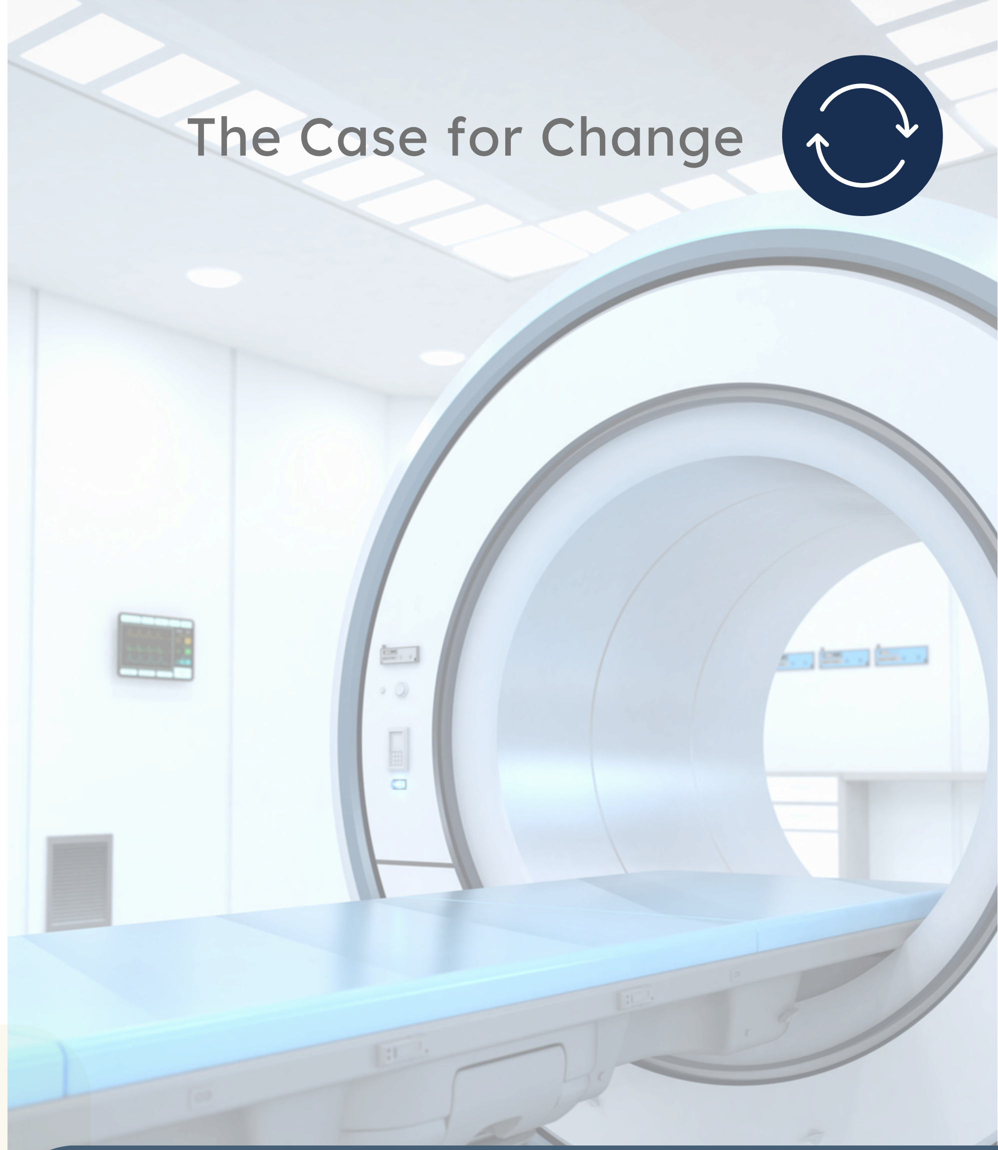
Human activity changing Earth's biophysical systems indirectly causes adverse impacts on human health (8):

- Reduced access to potable water due to reduced snowpack, depletion of aquifers, and the disturbed hydrologic cycle
- Population displacement and migration due to extreme weather events, water scarcity, starvation and sea-level rise
- Food insecurity due to decreased pollinators, decreased crop yields due to drought/flooding and reduced nutritional value of crops
- Increased interpersonal and international violence due to increasing heat, conflict over scarce resources, and forced migration
- Eco-anxiety and mental health issues

RESOURCES:

- Public Health and the Climate Crisis, World Health Organization
- Fact sheet - Climate change, World Health Organization

Climate Change and Health Equity



IMPACTS OF CLIMATE CHANGE ON HEALTH EQUITY

Climate health risks are disproportionately felt by the most vulnerable and disadvantaged individuals and groups including women, children, those with lower economic and financial means, displaced and underhoused persons, as well as those with underlying physical and mental health conditions (9).

Addressing Indigenous health needs and the structure of the Canadian public payer system are essential elements in crafting solutions that are both equitable and environmentally sustainable.

Investment in environmentally sustainable mobile and robotic imaging solutions that reduce patient travel improves health equity by providing local access to imaging services in rural, remote and Indigenous communities. Further evaluation is required to measure trade-offs of reduced emissions from patient travel against emissions related to operation and transport of mobile imaging equipment and teams.

Investments in health promotion, disease prevention, and early detection, including implementing and supporting imaging-based screening programs for breast cancer, lung cancer, coronary artery calcium, and CT colonography, reduce the burden of advanced disease and the associated resource intensive hospital care.

CANADIAN RURAL AND REMOTE ACCESS

A feasibility and cost analysis study of portable MRI in a remote setting in Canada found cost savings estimated $8 million over 5 years compared to travel to fixed site MRI, with improved access, triage and timeliness of care.

Telerobotic sonography provides an opportunity for improved access for rural and remote communities, improving health equity and reducing patient travel GHG emissions.

RESOURCES:

- Feasibility and Cost Analysis of Portable MRI Implementation in a Remote Setting in Canada, DesRoche et al. (2024)
- Economic Evaluation of Telerobotic Ultrasound Technology to Remotely Provide Ultrasound Services in Rural and Remote Communities, Adams et al. (2023)
- Planetary Health and Radiology: Why We Should Care and What We Can Do, McKee et al. (2024)

Healthcare's contribution to greenhouse gas emissions

GREENHOUSE GAS EMISSIONS AND HEALTHCARE DEMAND

Greenhouse gas (GHG) emissions arising from providing healthcare are a significant contributor to the global climate crisis. The healthcare sector accounts for 5% of total global GHG emissions. If healthcare was considered as a country, it would rank as the 5th largest emitter in the world. In Canada alone, the healthcare sector is responsible for 4.6% of the nation's total emissions (10).

The demand for healthcare services is rising due to aging populations and the increasing prevalence of chronic diseases. While there has been progress in reducing the carbon footprint of healthcare, the results have been mixed. For example, in the United Kingdom's National Health Service (NHS), there was a 62% reduction in CO_2 emissions per inpatient admission between 1990 and 2019. However, this led to only a 26% absolute reduction in emissions, reflecting the growing volume and complexity of healthcare services required to meet population needs (11).

GREENHOUSE GAS PROTOCOL

The Global GHG Protocol provides accounting standards and guidance that healthcare establishments can use to assess their emissions across three scopes (12). Percent of emissions of Canadian healthcare in each scope are described below

Scope 1 (Direct)

26% of emissions are from sources directly controlled by healthcare facility, primarily fossil gas boilers and anaesthetic gases.

Scope 2 (Indirect)

13% of emissions are from energy purchased from off site production, primarily electricity. May be generated by fossil fuels or renewables (13).

Scope 3 (Indirect)

61% of emissions are from the global healthcare supply chain, includes imaging equipment manufacturing, contrast production, medical supplies, food, travel, water use, ,and IT/data storage.

RESOURCES:

- Appendix C, Country Snapshots, Healthcare Without Harm
- Report: Greenhouse gas emissions estimation in Canadian healthcare systems, CASCADES
- Why aren't more doctors talking about climate change?, Vogel L. (2019)
- Planetary health care: a framework for sustainable health systems, MacNeill A, Forbes M, Sherman J. (2021)
- The Greenhouse Gas Protocol, (2004)
- Delivering a 'Net Zero' National Health Service, Figure 1: GHG scopes in the context of the NHS, NHS England
- Health sector emissions fact sheet - Canada, Global Road Map for Health Care Decarbonization - Key facts, Health Care Without Harm, ARUP. (2014)

Climate change and radiology

HOW RADIOLOGY TO CONTRIBUTES TO CLIMATE CHANGE

Radiology contributes to the climate crisis by generating GHG emissions and waste during the production and use phases of medical imaging equipment and supplies (4,14). Life cycle analysis suggests emissions per exam for MRI are 2-10 times that for CT and 15-35 times that for the US, the range due to variations in imaging components and electrical grid. Energy use accounts for just over half the total lifetime emissions of medical imaging equipment.

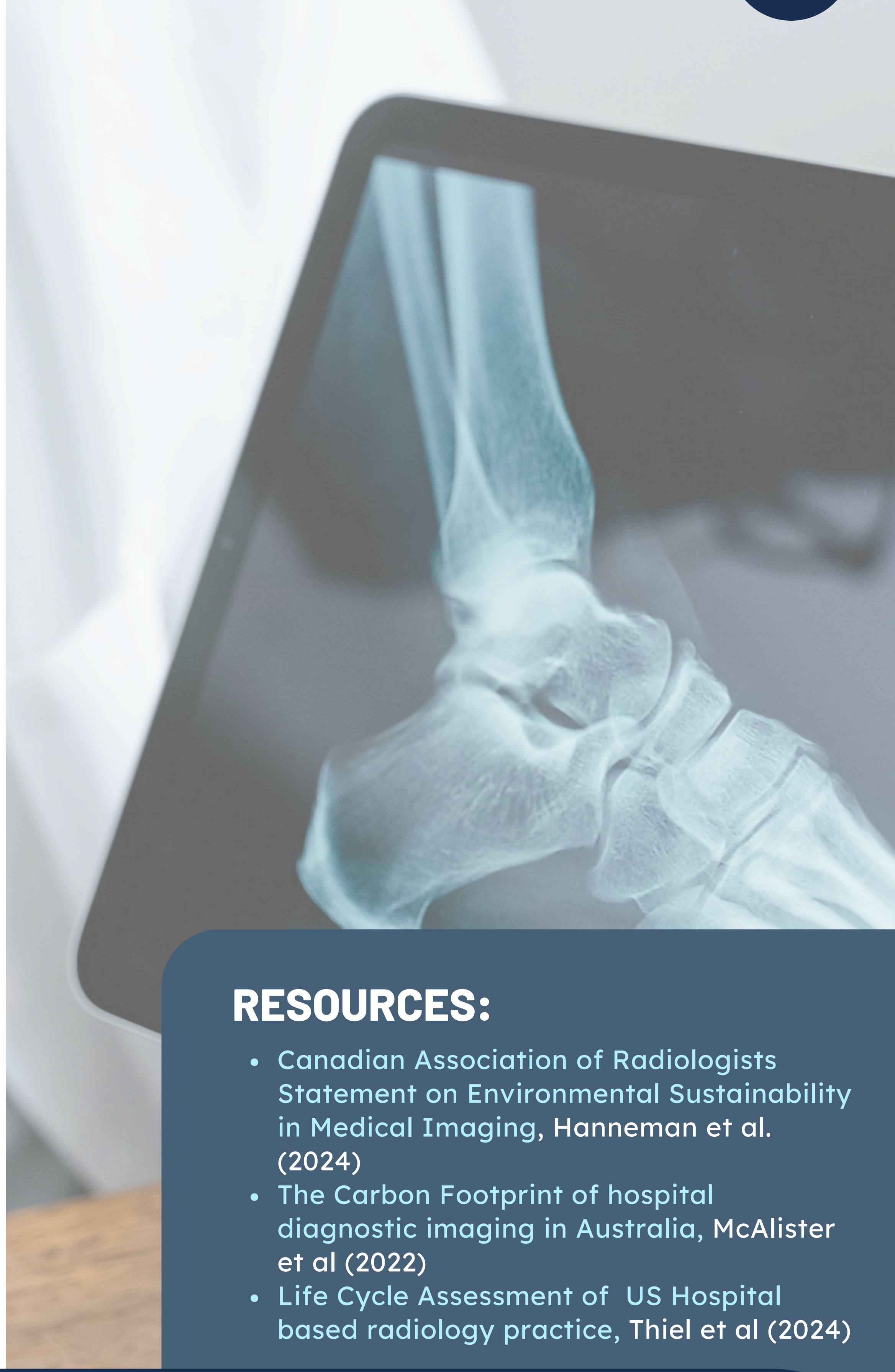
A negative feedback loop is established when poor air quality and heat events lead to increased utilization of medical imaging, which results in greater emissions (14).

Mitigation strategies to reduce GHG emissions and achieve net-zero, environmentally sustainable radiology departments are needed. At the same time, radiology departments must also adapt and build resiliency to current and future impacts of the climate crisis (15).

IMPACTS OF CLIMATE CHANGE ON RADIOLOGY

Climate change is already adversely affecting the health of Canadians due to wildfire smoke and poor air quality, increasing frequency and intensity of extreme weather events, and expansion of vector-borne and infectious illnesses (16). These health effects result in higher healthcare utilization, and increase emergency department medical imaging utilization (14).

Radiology departments are susceptible to equipment and infrastructure damage from flooding, extreme temperatures, and power failures, as well as workforce shortages due to injury and illness, potentially disrupting radiology services and increasing costs (17,18). Power loss or infrastructure damage resulting in the need to “quench” an MRI machine, or data loss due to overheating or power loss, may impair diagnostic imaging services for days/ weeks beyond the extreme weather event.



RESOURCES:

- Canadian Association of Radiologists Statement on Environmental Sustainability in Medical Imaging, Hanneman et al. (2024)
- The Carbon Footprint of hospital diagnostic imaging in Australia, McAlister et al (2022)
- Life Cycle Assessment of US Hospital based radiology practice, Thiel et al (2024)

MITIGATION VS. ADAPTATION

In healthcare, mitigation and adaptation are complimentary strategies. Mitigation is critical to reducing the adverse environmental impact of providing healthcare, while adaptation will be essential to resilience of healthcare systems in the face of now unavoidable impacts of our changing climate.
In this playbook, we will be focusing primarily on mitigation actions to reduce the contribution of medical imaging to air pollution, climate change, and biodiversity loss. The overall aim is reduce the negative impact on the environment and health, and to harness the health co-benefits of reduced emissions and waste.

Mitigation	Adaptation
Definition: reduce emission of greenhouse gases (GHG) into the atmosphere and/or enhance carbon "sinks" of soil, forests and oceans. The goal is to stabilize and reduce GHG levels to prevent the worst impacts of climate change (19).	**Definition:** Build resiliency to the impacts of climate change on the healthcare system and human health (20).
Examples in radiology: Scope 1 emissions: • Relax temperature controls in IR suites outside of regular hours Scope 2 emissions: • Reduce power consumption of equipment • Purchase electricity generated by renewables rather than gas or coal Scope 3 emissions: • Limit single use plastics • Include environmental impact/ sustainability in Request for Proposals (RFP) for purchase of supplies and imaging equipment All • Reduce low value imaging	Examples in radiology: • Engage and education all staff about extreme weather, changing disease patterns • Disaster planning to ensure rapid response and maintain access to care • Workforce planning to ensure adequate staffing during extreme weather events • Back-up systems to prevent power and/ or data loss • Building and structure preparedness to provide resiliency during floods, power loss, smoke, heat, hurricanes • Technology and IT upgrades with data redundancy to ensure continued provisions of medical imaging services during extreme weather events

WHAT

The Tools for Change

1. Education and Engagement of medical imaging department teams
2. Planetary health education for trainees
3. Energy Management
4. Travel and transportation
5. Procurement & Supply Chain
6. Reduce low value imaging

Sustainability Opportunities

Radiology Department

Education and engagement of medical imaging department teams	• Educate staff to understand health effects of climate change and health co-benefits of reducing emissions • Promote research and sustainable quality improvement
Energy Management	• Power off equipment when not in use • Optimize patient scheduling to reduce idle time
Travel & transportation	• Encourage staff commute by active transport (walk, bike, transit) • Telemedicine • Offer virtual/ hybrid conference attendance • Support work from home where possible

Facilities/Systems Level

Buildings	• Relax interventional radiology (IR) suite climate control in non-operational hours to reduce building energy use/ emissions • Waste sorting/ management
Procurement & Supply Chain	• Include sustainability in procurement contracts • Purchase refurbished equipment • Reusable gowns, linens, sharps containers • Reduce single use plastics
Reduce low value imaging	• Encourage use of Appropriateness Criteria: Choosing Wisely and American College of Radiology • Advocate for clinical decision support tools • Reduce duplicate exams through digital health systems

Education and engagement of medical imaging teams

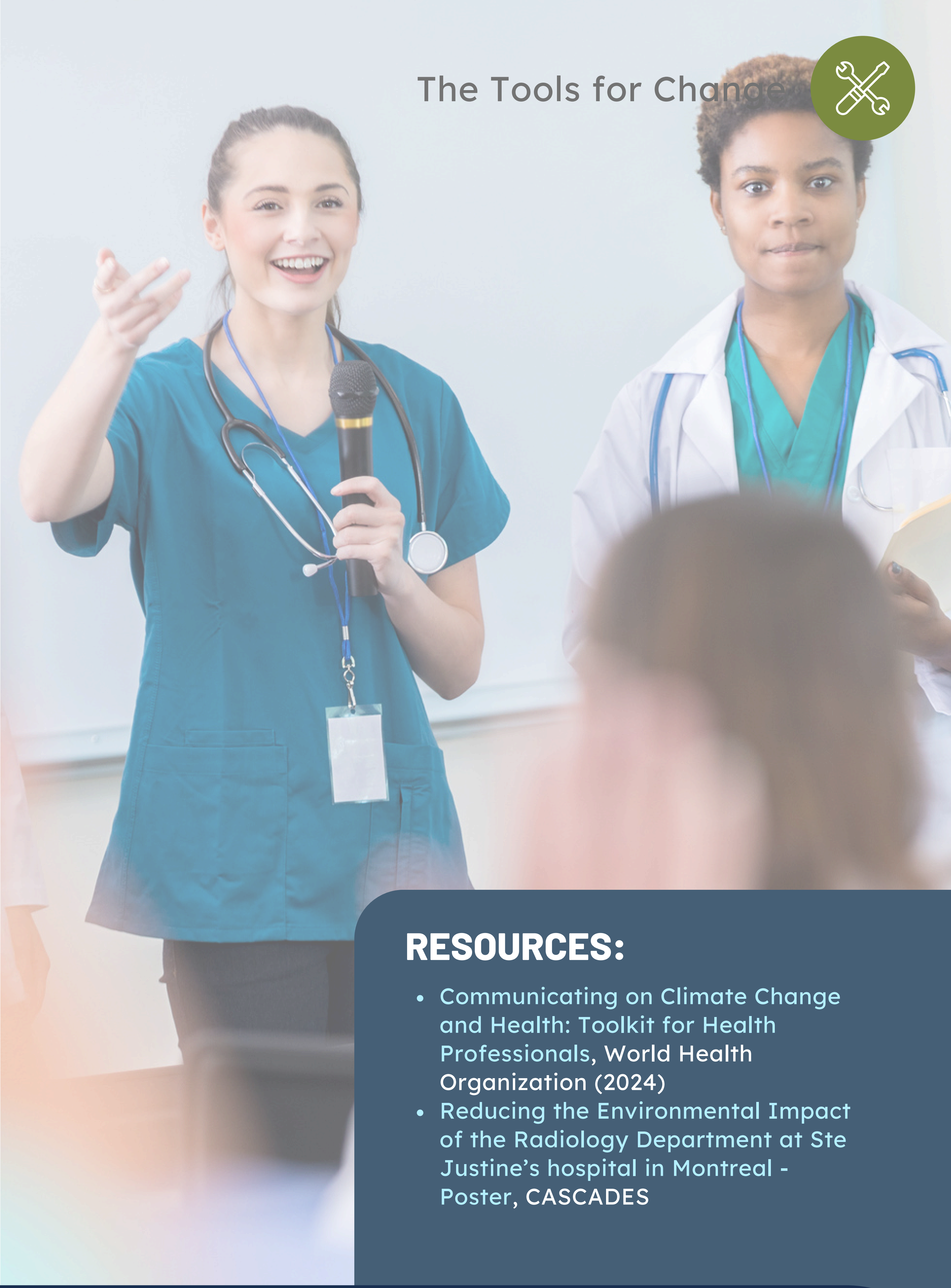
Education around the causes of climate change, the contribution of providing healthcare to GHG emissions and the health impacts of climate change can help engage medical imaging teams in environmentally sustainable action

ESTABLISH AWARENESS AMONGST ALL DEPARTMENT STAFF

Understanding the health impacts of climate change and air pollution is key to engaging radiology staff in sustainable practices. These environmental factors contribute to conditions commonly seen in imaging, such as cardiorespiratory disease, heat-related illness, and cancer.

Educating medical imaging teams on these links supports more responsive, low-emission workflows that improve patient care while reducing environmental impact.

By adopting measures like optimized imaging protocols and limiting single-use items, radiology departments can reduce emissions and resource use. This positions teams to lead by example—showing how climate-conscious practices can advance both health outcomes and healthcare sustainability.



RESOURCES:

- Communicating on Climate Change and Health: Toolkit for Health Professionals, World Health Organization (2024)
- Reducing the Environmental Impact of the Radiology Department at Ste Justine's hospital in Montreal - Poster, CASCADES

Planetary health education for trainees

Radiologists are well positioned within the healthcare system to lead transformative change to low-carbon, high quality, climate resilient healthcare.

The goal of Planetary Health education for Radiology trainees is to equip future radiologists to lead mitigation and adaptation efforts. Objectives include:

- Recognize the anthropogenic etiology of the climate crisis and impacts of the climate crisis on human health
- Recognize the contribution providing healthcare, with a focus on medical imaging, makes to the climate crisis
- Recognize the risks to stability of the healthcare system due to extreme weather events
- Development of sustainability related research and sustainable QI, including dedicated time and project funding

Academic radiology departments have a responsibility to provide leadership in environmentally sustainable radiology concepts to support incorporation throughout Diagnostic Radiology CanMEDS competencies.

Figure: Planetary Health.

One health is the health of all life on earth

Planetary health is the whole living and nonliving system and recognizes that human health is inextricably linked to the health of our planet. As human health is directly linked with planetary health, understanding and acting upon threats to planetary health is critical to our long-term well-being.

RESOURCES:

- Towards an educational praxis for planetary health: a call for transformative, inclusive, and integrative approaches for learning and relearning in the Anthropocene, Redvers et al. (2023)
- Figure: Canadian Association of Radiologists Statement on Planetary Health Education in Radiology, Brown et al (2024)

Energy Management

Radiology departments are high consumers of energy and materials, with high production phase (raw material to manufacture and delivery) and use phase (energy to operate) emissions

The production phase of one MRI machine consumes an estimated 753,000 kWh of energy, which is equivalent to the emissions produced by 73 gas-powered cars over one year.

Energy use and emissions during the operational phase vary depending on the type of exam and the source of electricity generation, whether from fossil fuels or renewable sources. The cumulative energy use for MRI and CT scanners is significant. For instance, a Swiss teaching hospital with three CT scanners and four MRI machines accounted for 4% of the hospital's total energy consumption (21). In this study, one CT scanner used as much energy annually as 5 four-person households, while one MRI scanner uses the energy equivalent of 26 four-person households.

Some CT scanners use up to 2/3 of their total energy consumption during the idle system state, and powering down existing CT scanners to a lower energy state in non-operational hours saves energy and cost. New and upgraded medical imaging equipment developed by vendors will include systems with lower power idle states, automatic power down when not in use for a period of time, and state of the art real time energy use modulation.

RESOURCES:

- Environmental Impacts of Abdominal Imaging: A Pilot Investigation, Martin et al. (2018)
- Energy Consumption of Radiology: Energy and Cost-saving Opportunities for CT and MRI Operation, Heye et al. (2020)
- GHG equivalencies calculator, United States Environmental Protection Agency
- Energy and Greenhouse Gas Emission Savings Associated with Implementation of an Abbreviated Cardiac MRI Protocol, Ibrahim et al. (2024)
- Ecodesign and Operational Strategies to Reduce the Carbon Footprint of MRI for Energy Cost Savings, Woolen et al. (2023)
- Quantitative Assessment of CT Energy Use and Cost Savings Through Overnight and Weekend Power Down in a Radiology Department. Brown et al. (2023)

MRI : ENERGY USE OPTIMIZATION

Approximately 50% of MRI scanners are not placed in lower power mode during non-productive hours. Powering down MRI machines in nonoperational hours saves an estimated 33% of energy costs. If all outpatient MRI machines in the US were placed in power save mode overnight, it would save $8.2-10.7 million US $ and 41-52 MTCO2e. This practice can lead to energy savings of over 55,000 MWh, which is comparable to the energy consumption of a town with 5,500 residential homes (22).

Several opportunities exist to further reduce emissions and the environmental impact of MRI usage. Optimizing protocols by eliminating redundant sequences, accelerating image acquisition, and minimizing idle time can improve efficiency. The adoption of AI applications to reduce image acquisition time and low-field and low helium MRI technologies can also contribute to energy savings.

Optimizing patient scheduling to reduce idle time helps ensure that MRI scanners are used efficiently, reducing unnecessary energy consumption.

REDUCED GHG EMISSION SAVINGS FROM AN ABBREVIATED CARDIAC MRI PROTOCOL

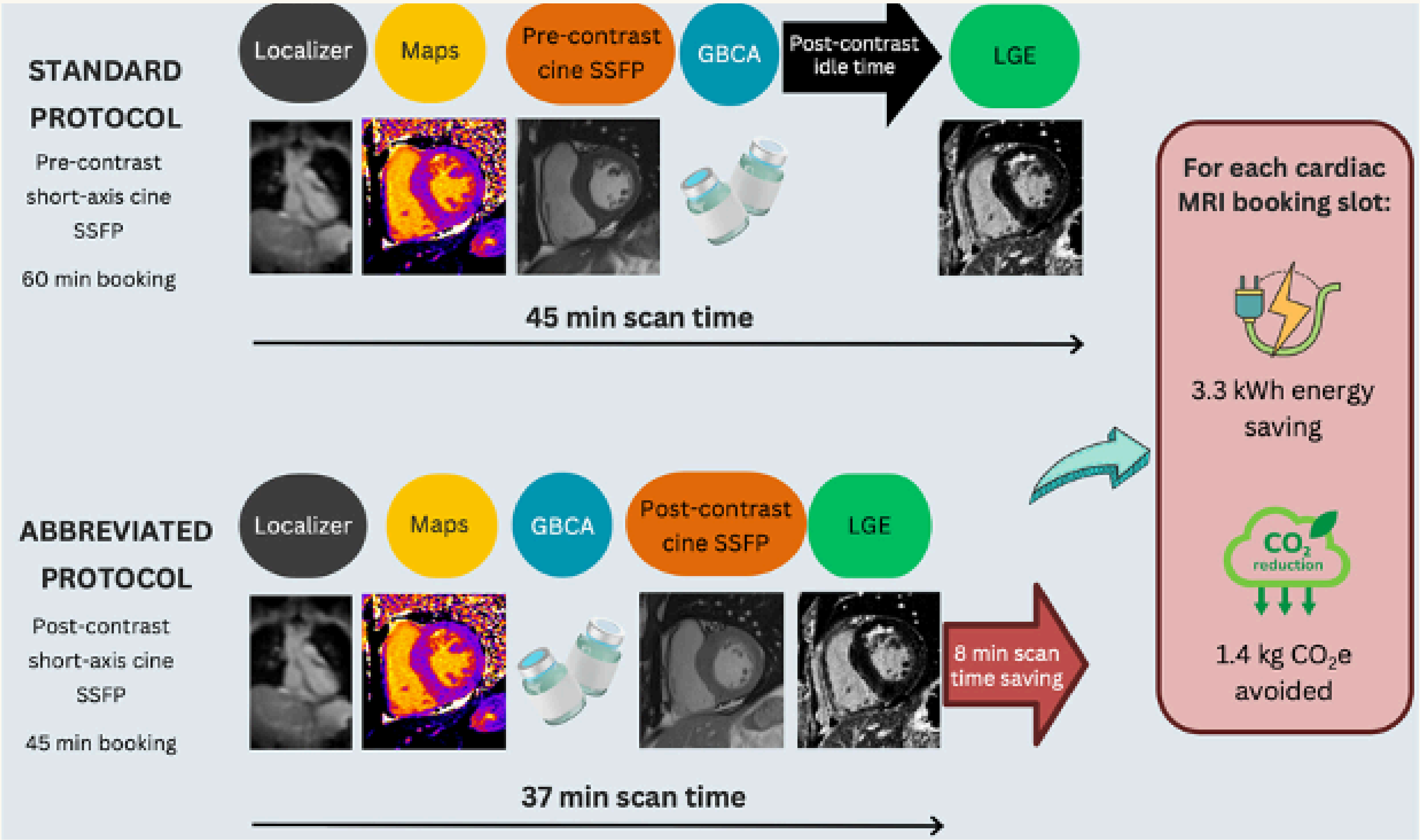


Fig:Ibrahim et al 2024 Radiology (23)

Standard cardiomyopathy cardiac MRI protocol was abbreviated by moving the short-axis cine steady-state free precession acquisition after contrast material injection Resulting in mean 3.3 kWh energy savings and 1.4 kg CO2 equivalent avoided per MRI examination (23)

CT SCAN : ENERGY USE OPTIMIZATION

Up to two-thirds of the total energy consumed by CT scanners may occur during idle or non-clinical hours (21). Improving energy efficiency during the workday can include optimizing patient scheduling to reduce idle time between patients, and collaboration with vendors to develop lower energy standby power modes that do not impact workflow, radiation dose or patient care.

Energy and cost savings are available when CT scanners are placed into lower power modes in nonoperational hours, where clinically appropriate. A study to measure potential energy and cost savings through CT scanner power down in non-operational hours was conducted in a British Columbia hospital. Power data loggers were placed on the CT scanner and power measured in ready to scan mode (orange); gantry off/computer on mode (green) and gantry off/ computer off mode (blue) (24).

The results showed that powering down a single scanner overnight saved 14,148 kWh per year which is equivalent to driving 25,760 miles in a gas car (EPA GHG equivalencies calculator).

Subsequent regional modeling study involving 12 scanners, co-ordinated with clinical use data, found that powering down overnight at selected sites resulted in annual savings of > 250,000 kWh, which would power approximately 169 electric cars for a year

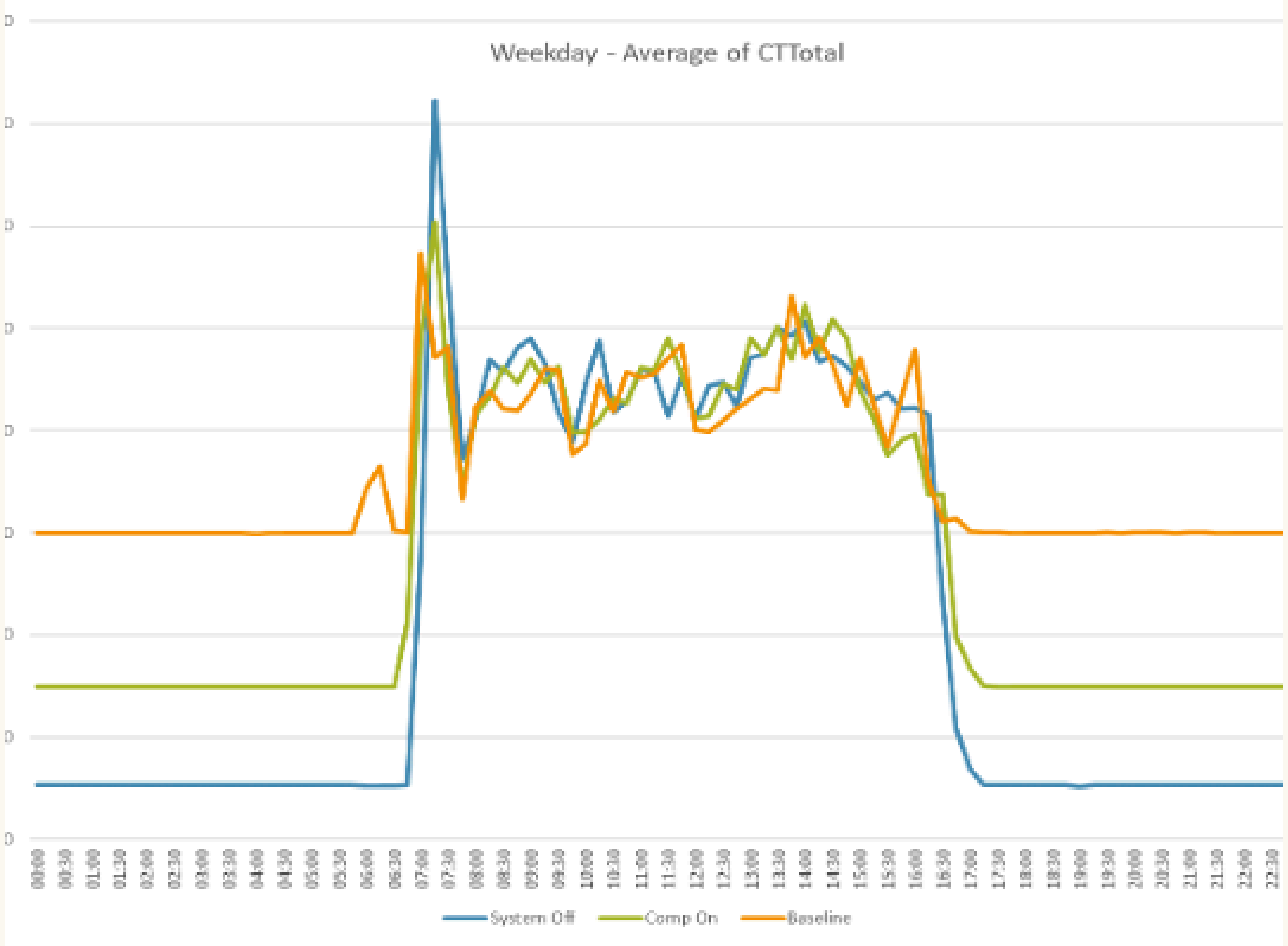


Fig: Brown et al 2023 CARJ (24)

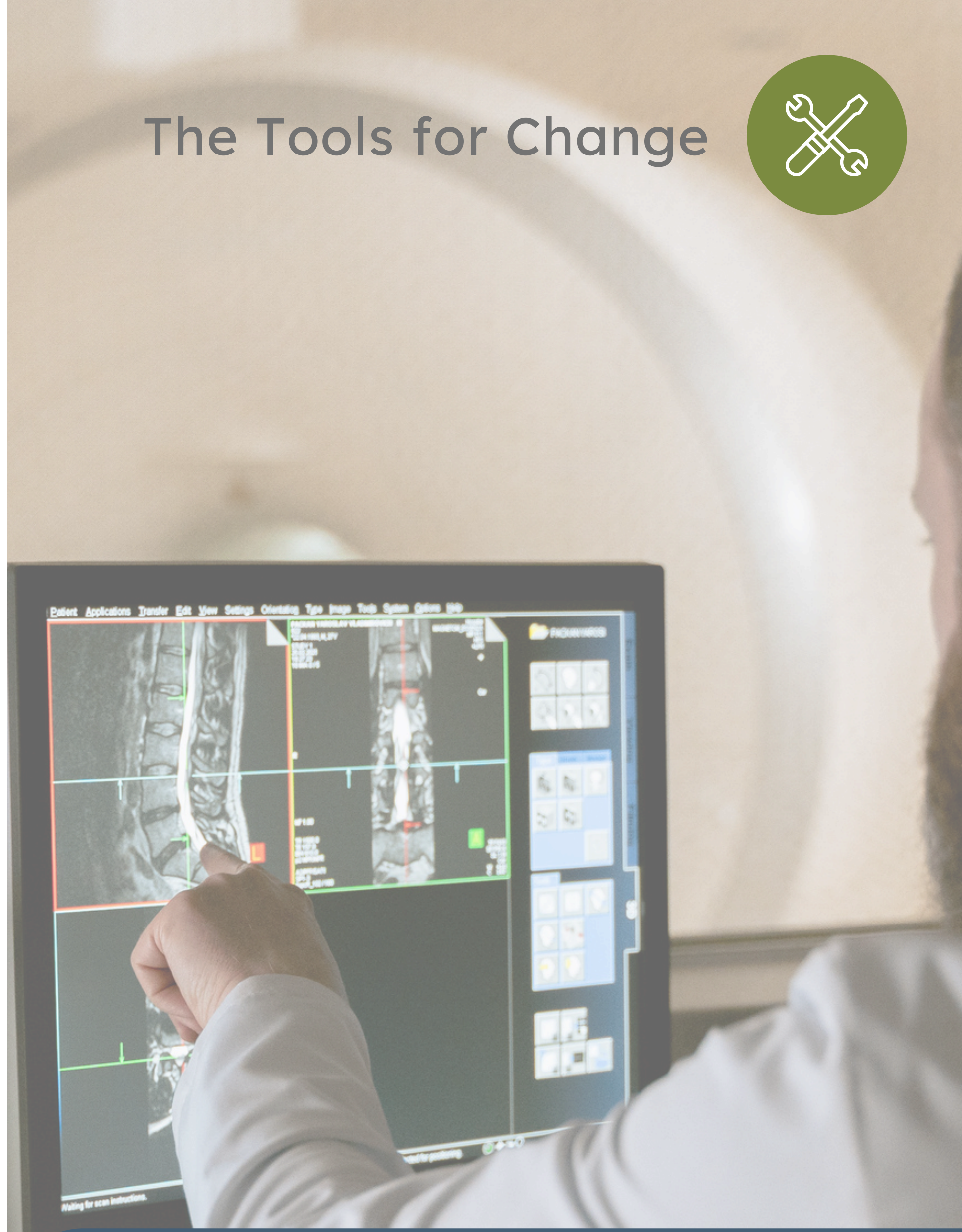
PACS AND COMPUTERS

Radiology department PACS (Picture Archiving and Communication System) stations, desktop computers, and laser printers are often left running 24/7,using energy with no benefit to patient care. By powering down these systems after hours or putting them in sleep mode, facilities can make a substantial impact on reducing energy use and saving electricity costs (25).

Turning off PACS stations, laser printers, and computers when not in use can dramatically reduce energy consumption. Studies show that workstations in standby mode consume 54% less energy compared to continuously running systems.

A study in a radiology department with 29 desktop computers and 25 PACS stations found that powering down these devices overnight would save 25,040 kWh of energy, which translates to preventing 17.7 tons of CO2e emissions and saving US$7,253 annually. This energy savings is roughly equivalent to taking 10 internal combustion engine cars off the road for a year. However, the study found the energy savings were not realized when powering down was left to individual operators (26). A recent study in the UK found an automatic shutdown protocol for PACS workstations outside regular working hours reduced electricity use by 50% and was well received by radiologists (27).

As AI tools are developed for radiology, energy use must be included in purchase and implementation decisions. Data centers are large consumers of electricity, and selection of services provided using electricity generated by renewables rather gas or coal will reduce the associated emissions. Ongoing work will be required to optimize the advantages of AI with the trade-off of the energy required to develop and operate AI tools



RESOURCES:

- Switching off for future-Cost estimate and a simple approach to improving the ecological footprint of radiological departments, Buttner et al. (2020)
- "EcoRadiology"-pulling the plug on wasted energy in the radiology department, McCarthy et al. (2014)

INTERVENTIONAL RADIOLOGY (IR) SUITES

HVAC (heating, ventilation and air-conditioning) systems account for a significant portion of GHG emissions of interventional radiology (IR) suites. As with operating rooms, IR suites require strict temperature and air exchange controls, which increase energy use and Scope 1 emissions. Optimizing the design, construction, and maintenance of HVAC systems can greatly reduce their environmental impact

WASTE HEAT RECOVERY AND SYSTEM OPTIMIZATION

Implementing waste heat recovery systems allows energy generated by epuipment cooling processes to be reused elsewhere in the facility, reducing overall energy demands. Regular maintenance also ensures systems operate efficiently, minimizing energy waste and prolonging equipment life

ROOM RENOVATION AND MEDICAL EQUIPMENT RETROFIT

When renovating IR suites or upgrading medical imaging equipment, establishing clear guidelines focused on maximizing recycling opportunities, optimizing waste distribution streams, and utilizing post-consumer recycled materials in rebuilds. Adopting a lifecycle approach to medical imaging equipment, from installation to disposal, can help minimize environmental impacts and energy use.

IR SUITE LCA AUDIT

Strategies for IR suites to reduce HVAC emissions:

- Permitting a wider range of temperature and humidity control during off-hours
- Decrease frequency of air exchanges during off hours
- Install occupancy sensors to minimize energy use during off-hours

SPECIFIC STRATEGIES FOR OPTIMIZING HVAC IN IR SUITES

Allowing climate control systems to operate with a wider range of temperature and humidity settings during off-hours, installing occupancy sensors and decreasing the frequency of air exchanges when rooms are not in use can help reduce energy use.

POLICY RECOMMENDATIONS

Developing facility-wide guidelines for sustainable HVAC practices is key to ensuring consistency and long-term energy savings. Continuous monitoring of energy use through tracking systems can inform further improvements, while staff training on energy-efficient practices can foster a culture of sustainability.

RESOURCES:

- The Environmental Impact of Interventional Radiology: An Evaluation of Greenhouse Gas Emissions from an Academic Interventional Radiology Practice, Chua et al. (2021)
- Canadian Association of Radiologists Statement on Environmental Sustainability in Medical Imaging, Hanneman et al. (2024)

Travel and Transportation

Commutes can be made more sustainable through encouring public transit, ridesharing, cycling initiatives. Support work from home to reduce staff commuting trips where appropriate.

Encouraging active transportation like walking or cycling reduces local air pollution while providing health benefits to the individual, including improved cardiorespiratory fitness, mental health, reduced risk of some cancers, and improved cancer survival.

In the UK, patient transportation accounts for 17% of the National Health Service (NHS) carbon footprint (28). Mobile imaging, by bringing the imaging to the patient, reduces the need for patient travel. Continuous evaluation of trade-offs of emissions from transporting and operating mobile equipment will be required. As mobile imaging services expand to further rural and remote areas of Canada health equity and access is improved.

In Canada, seven publicly funded mobile MRI units serve twelve rural communities across five provinces, each reducing patient travel by up to 380 kilometers. Each unit performs 150 to 3,000 exams per community over several days, cutting down vehicle and flight emissions.

Mobile imaging supports breast and lung screening programs. In British Columbia, 8% of mammography exams are conducted with mobile equipment. Mobile CT screening for lung cancer is available in an increasing number of provinces.

VEHICLE EXHAUST REDUCTION

Reducing vehicle exhaust has immediate community health benefits (29).

- In a suburb of Los Angeles, the replacement of 2% of gas-powered cars with electric vehicles led to a reduction in nitrogen dioxide (NO2) levels by 0.41 parts per billion. This decrease in air pollution contributed to a 3.2% reduction in the annual age-adjusted rate of asthma-related emergency room visits.

RESOURCES:

- California's early transition to electric vehicles: Observed health and air quality co-benefits, Garcia et al. (2023)
- Canadian Medical Imaging Inventory Report 2022-2023, Canada's Drug Agency

VIRTUAL AND HYBRID MEETINGS AND CONFERENCES

Aviation contributes approximately 4% to global emissions. A single round-trip flight from Vancouver to Toronto, for example, can use up to 50% of an individual's annual carbon budget of 2.5 tCO_2e (30). While attendance at professional conferences and meetings has benefits beyond the academic, a commitment to sustainable practices can make a significant difference in reducing overall emissions.

An effective strategies is to critically evaluate the need for travel. Is attending a conference or meeting in person professionally and personally justified? By asking this question, departments can avoid unnecessary trips and their associated carbon costs. Virtual and hybrid meetings offer an excellent alternative, reducing the carbon footprint of professional gatherings by up to 100 times compared to large in-person meetings that require air travel. Additionally, these platforms promote more equitable access, enabling broader participation without the constraints of travel costs or geographic limitations.

When travel is unavoidable, sustainable modes of transportation such as trains or buses should be prioritize over air travel. However, if air travel is necessary, the traveller can calculate the carbon footprint of their trip and consider it in the context of the recommended individual carbon budget of 2.5 tCO_2e per year. This conscious approach helps ensure that travel decisions align with both personal and departmental sustainability goals.

By fostering a culture that promotes sustainable travel and leverages virtual platforms, radiology departments can significantly reduce their environmental impact while still fulfilling professional obligations (31).

An example in medical imaging is the expansion by Radiopedia of free-access to 125 low- and middle-income countries to online radiology courses and online virtual conference

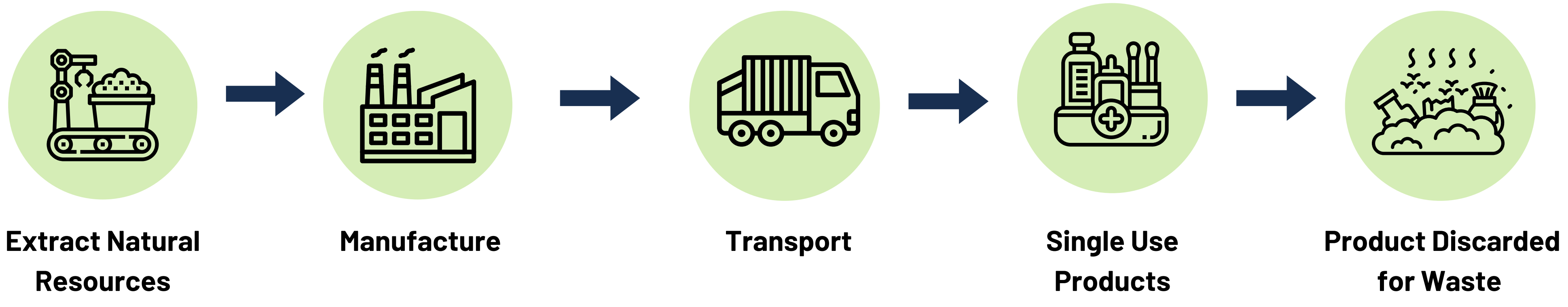
RESOURCES:

- Explore The Climate Impact of Flying, Calculate Your Flight Emissions! , Flight Free USA
- Virtual Care Carbon Accounting Tool, CASCADES

Procurement & Supply Chain

Healthcare supply chains are often linear: resources are used once, then discarded. This model is costly and wasteful. A circular approach offers a more sustainable alternative by reusing, repurposing, and recycling materials to reduce both waste and resource use.

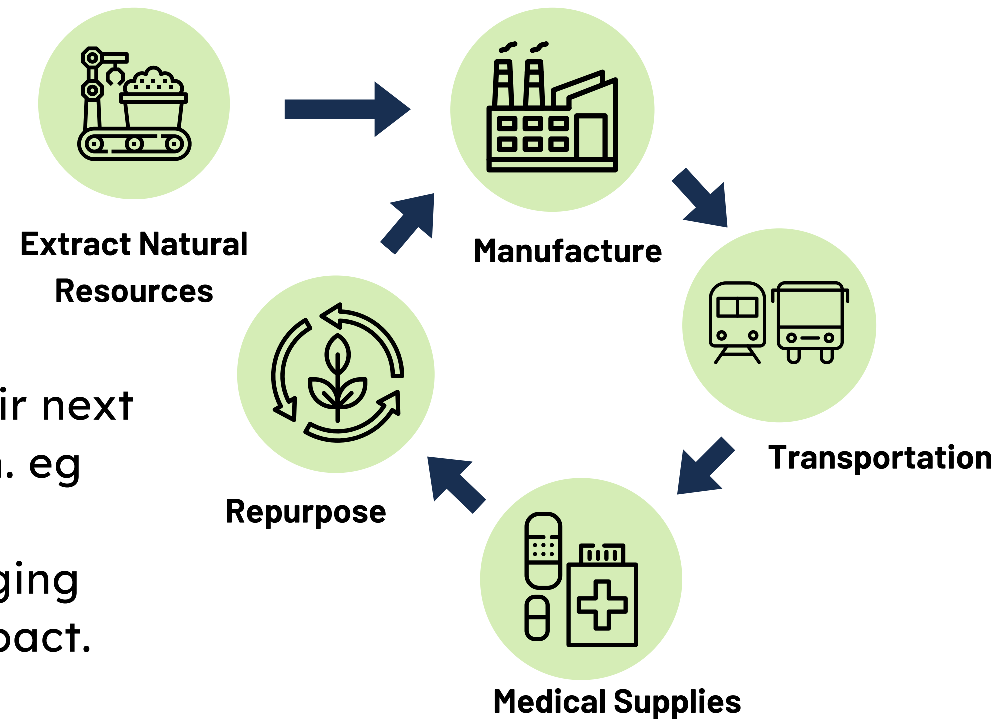
LINEAR SUPPLY CHAIN

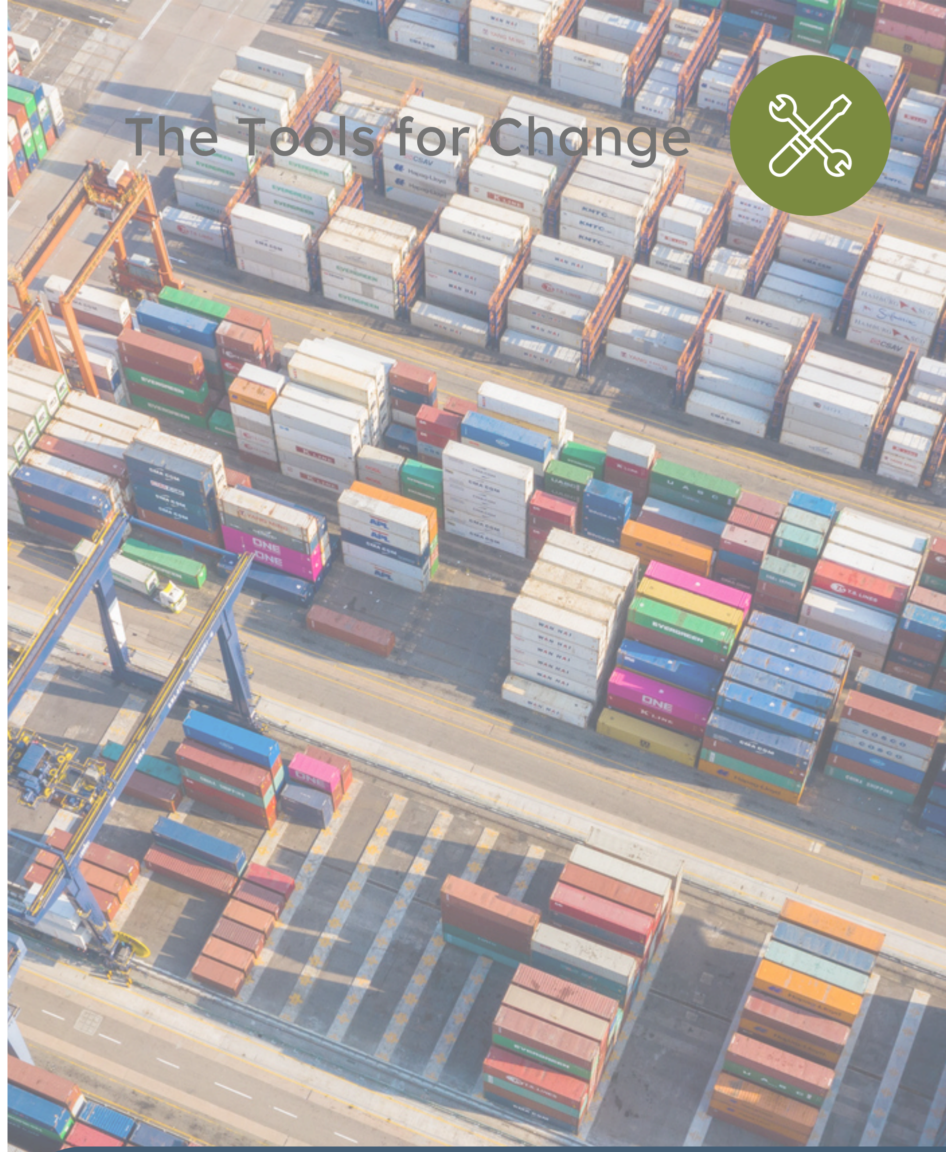


A linear supply chain is a one way process: raw materials are extracted, products are designed for a single use, transported, utilized and then disposed to waste. This is expensive and creates continuous demand for raw materials and for landfill/incineration.

CIRCULAR SUPPLY CHAIN

In a circular supply chain, products are reused, repurposed, recycled to their next best use, to minimize resource consumption and minimize waste generation. eg spent surgical gowns can be reused as nonsterile PPE, then shredded for upholstery stuffing. Vendor supported updated or refurbished medical imaging equipment offers considerable cost savings and reduced environmental impact.





RESOURCES:

- Climate Change and Radiology: Impetus for Change and a Toolkit for Action, Brown et al. (2023)
- Modeling the Environmental and Financial Impact of Multi-dose vs. Single-dose Iodinated Contrast Media Packaging and Delivery Systems, Lindsey et al. (2023)
- 2020 Environmental Performance Accountability Report for Fraser Health, BC GreenCare

REFUSE, REDUCE, REUSE, REPURPOSE, RECYCLE

Medical imaging generates a large amount of waste: one tertiary care IR department generated 23,500kg CO2 in a 5-day workweek (equivalent to 10 000L gas burned).

Adopting a hierarchical framework to guide sustainability efforts in radiology departments can significantly reduce environmental impact. This framework emphasizes minimizing waste at every stage of the supply chain, from procurement to disposal. Examples in radiology that can be applied within this framework include:

- Refuse/Reduce: In interventional radiology (IR) procedures, only open the supplies that are necessary for the case.
- Reuse: A hospital in British Columbia saved $2 million between August 2020 and February 2021 by replacing disposable gowns with reusable ones. This change also led to a 50% reduction in emissions associated with gown use (32).
- Repurpose: Spent reusable sterile gowns can be repurposed for non-sterile personal protective equipment (PPE), extending their life cycle and reducing the need for new materials.
- Recycle: Ensuring that there is a solid infrastructure in place for recycling and composting non-medical waste is crucial.
- Disposal: Disposal is the least favored option. Proper disposal avoids environmental contamination and ensures compliance with waste management regulations.

The Rs of Waste Management

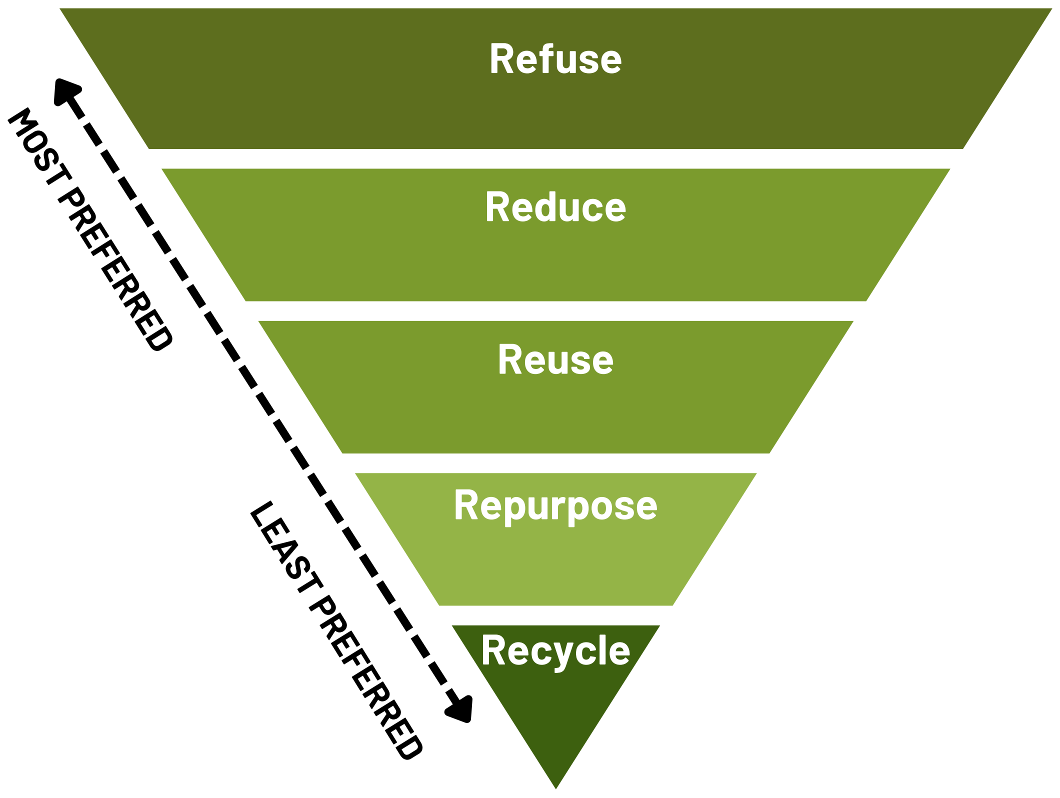


Fig: Chaban et al 2023 JMRI

REDUCE/RECYCLE: IV CONTRAST

REDUCE WATERBODY CONTAMINATION WITH CT AND MRI CONTRAST MEDIA

By adopting multi-dose contrast delivery systems and implementing recycling protocols for iodine-based agents, radiology departments can contribute to a more sustainable practice with no impact on patient care.

Switching from single-dose to multi-dose intravenous (IV) contrast delivery systems offers a substantial environmental and economic advantage. A multi-dose system can reduce contrast waste by 73%, plastic waste by 93%, and overall costs by 35% (33).

Iodine in contrast agents is a non-renewable resource, primarily sourced from brines extracted from oil and gas extraction, predominantly (96%) in Japan and Chile (34). When iodine-based contrast agents are poured down the drain, they are not captured by current municipal water treatment processes, and can form toxic byproducts with disinfectants, posing additional environmental risks. To reduce this, leftover contrast at the end of the day should be captured in designated containers and returned to the manufacturer for reuse or repurposing.

This approach both conserves a valuable resource and reduces the environmental impact associated with iodine disposal.

INCORPORATE SUSTAINABILITY INTO PROCUREMENT PROCESSES

Incorporating sustainability into procurement in medical imaging involves embedding environmentally responsible criteria into selection and purchasing decisions. From choosing energy-efficient imaging devices to sourcing supplies with minimal packaging, sustainable procurement practices in radiology can support both environmental and health goals.
This table offers proposed wording that could be incorporated into request for proposal (RFP)'s for medical imaging, with gradually increased weighting within the RFP as emphasis on reducing Scope 3 emissions increases (35).

Corporate policies	• What is your corporate climate action plan? • What is your carbon reduction plan for your Scope 1, 2 and 3 emissions? • How is your company addressing corporate and governance ESG responsibilities
Manufacturing	• How are greenhouse gas emissions and waste reduced during manufacturing? • How much energy, water and what chemicals does the product take to produce? • What strategies are used to reduce waste in the manufacturing process?
Packaging and distribution	• What percent of packaging is made from post-consumer recycled materials? • Does the packaging generate waste? How is it recycled/ disposed? • How are emissions from transportation kept to a minimum?
Energy use	• Does the product meet the US EPA Energy Star Specifications for Medical Imaging Equipment or European Union Geen Public Procurement specifications ?
Reduce, reuse, refurbish, repurpose, recycle	• What end-of-life recycling or disposal procedures are in place for the product? • Can software updates be done remotely to keep equipment current? • What are the environmental Life Cycle Assessments of the product?

Reduce Low Value Imaging

Addressing low value imaging is a system concern, requiring broad partnership and collaboration of referring providers, patients/families, and healthcare leadership

Healthcare systems, in collaboration with partners including radiologists, referring clinicians, administrators, patients/families and hospital information technology, should embed clinical decision support tools in shared digital clinical information systems to reduce low-value imaging, and align with appropriate use guidelines while ensuring capacity to meet current and future medical imaging needs.

Canadian Institute for Health Information (CIHI) and Choosing Wisely Canada 2022 review of 12 treatments and tests found improvement over 5 years however, of 12 chosen tests and treatments measured across community, ER and hospital care, 4 did not decline in usage, and of those, 2 were imaging exams. These were imaging for low back pain without red flags and CT for minor head trauma without red flags. (36)

	The Canadian Association of Radiologists (CAR) and Choosing Wisely have provided guidelines aimed at reducing unnecessary imaging procedures (37). The following recommendations, issued in 2025, highlight situations where imaging is not advised:
1.	Don't do imaging for lower-back pain unless red flags are present.
2.	Don't do imaging for minor head trauma unless red flags are present.
3.	Don't do imaging for uncomplicated headache unless red flags are present.
4.	Don't do computed tomography (CT) for the evaluation of suspected appendicitis in children until after ultrasound has been considered as an option.
5.	Don't do an ankle X-ray series in adult for minor injuries.
6.	Don't order MRI without first considering ultrasound for the assessment of rotator cuff pathology and bursitis.
7.	Don't order MRI of the hip just based on x-ray features of femoroacetabular impingement unless there are clinical signs and symptoms of joint impingement.
8.	Don't order MRI of the hip or knee when X-ray demonstrates greater than mild osteo arthritis, unless recommended by a musculoskeletal specialist.

HOW

The Strategy for Change

1. Clinician Leadership
2. Senior executive and operations leadership
3. Procurement Teams
4. Industry Collaboration
5. Environmental impact of AI in radiology

Clinician leadership: Planetary Health education and CanMEDS roles

Medical Leadership: environmental sustainability and responsible resource use is recognized as a domain of quality improvement and essential to individual patient and public health.

COMMUNICATOR

- Climate change impacts patients and healthcare.
- Climate impacts disproportionately affect individuals and communities vulnerable to adverse social and environmental determinants of health.

HEALTH ADVOCATE

- Social and environmental determinants of health create inequity and vulnerability to climate change.
- Engaging vulnerable communities in solutions to their specific vulnerabilities is an important component of QI.

COLLABORATOR

- Cross disciplinary collaboration will support the role of diagnostic imaging in transformative low carbon, high quality, sustainable, climate resilient healthcare.

PROFESSIONAL

- Environmentally sustainable radiology is complex and rapidly evolving.
- A commitment to lifelong learning about Plantetary Health will enable rapid response and leadership as the climate crisis evolves.

SCHOLAR

- Inclusion of Planetary Health content in education, research, and QI is necessary to establish robust database to support low-carbon, high-quality, climate resilient radiology in Canada.

LEADER

- Commitment from radiology residency programs to support engagement of trainees in PH initiatives is required to remove barriers and embed sustainability as foundational to QI.

Senior Executives and Operations Teams

Sustainability is a team sport requiring vigorous engagement at all levels of hospitals and health institutions, and Radiologists can lead this.

ENGAGE WITH SENIOR EXECUTIVES TO REDUCE SCOPE 1 AND 2 EMISSIONS

Radiologists can engage with healthcare leadership to advocate for reducing emissions though:

Scope 1: Direct emissions onsite/ buildings controled by the healthcare organization: investment in clean energy infrastructure such as solar, geothermal, and wind energy instead of fossil gas boilers

Scope 2: Indirect emissions from purchased off site energy generation, primarily electricity Advocate for the purchase of electricity generated from renewable sources over fossil fuels when possible is a high impact opportunity to reduce GHG emissions.

Senior executive teams can support sustainable quality improvement efforts through securing seconded time and project funding for sustainability initiatives.

Advocating for system level implementation of multidisciplinary clinical decision tools can save money, reduce waitlists and reduce emissions through reducing low-value imaging, improving operational efficiency and resource utilization (38).

RESOURCES:

- Radiology in Our Changing Climate: A Call to Action, Schoen, J., McGinty, GB., & Quirk, C. (2021)

Procurement Teams

COLLABORATE WITH PROCUREMENT TEAMS TO REDUCE SCOPE 3 EMISSIONS

- Add sustainability criteria to RFPs for medical imaging equipment
- Encourage increasing weighting of environmentally sustainable criteria in purchase decisions
- Support purchase of reusables and infrastrucure for reprocessing where appropriate
- Collaborate with vendors and procurement teams to identify opportunities for updating and refurbishing medical imaging equipment (circular supppy chain), rather than all new (linear supply chain)
- Adhere to the principals of a circular supply chain, and re-use, repurpose and recycle supplies when feasible

REFURBISHED MEDICAL EQUIPMENT

Good Refurbishment Practice (GRP) is defined as “process of combination of processes applied during the expected service life to restore used medical imaging equipment to a condition of safety and effectiveness comparable to when new”.

- Reduces cost of ownership
- Significantly reduces production phase emissions
- Medical Imaging and Technology Alliance (MITA) provides guidelines and frameworks for safe use of refurbished medical imaging equipment.

RESOURCES:

- Good Refurbishment Practices for Medical Imaging Equipment, National Electrical Manufacturers Association (NEMA). (2016)

Industry Collaboration

Industry partners, vendors, procurement teams, and radiologists should prioritize the development of medical imaging equipment with lower energy requirements and automated low-power modes for idle and off states.

Exploring low-field MRI and other emerging medical technologies with reduced energy consumption and associated greenhouse gas emissions is advisable where appropriate. Investing in low- or no-helium MRI systems, along with processes to recycle or recapture helium used for cooling, can reduce environmental impact.

Additionally, implementing policies to guide the appropriate use of ultrasound-enhancing agents and providing education on their direct environmental impact—particularly as fluorinated gases with high global warming potential—is important.

Policies should also focus on reducing the environmental impact of administered radiopharmaceuticals and minimizing radioactive waste in nuclear medical imaging. By collaborating on these initiatives, the medical imaging field can make meaningful strides toward reducing its environmental footprint.

RESOURCES:

- Canadian Association of Radiologists Statement on Environmental Sustainability in Medical Imaging, Hanneman et al. (2024)

Environmental impact of radiology AI

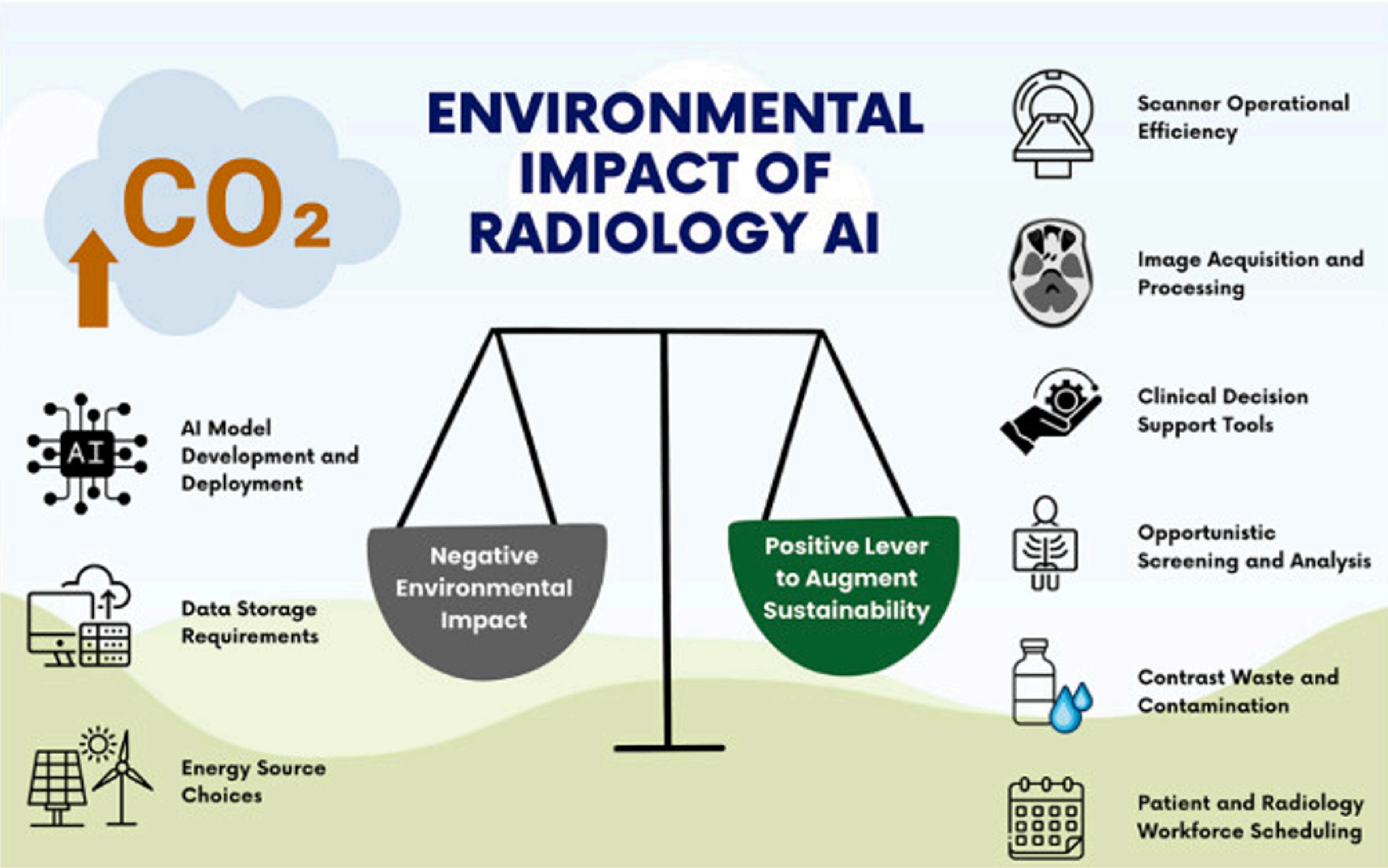
The development and deployment of AI models in Radiology is energy intensive and generates a large amount of greenhouse gases (Scope 2 emissions) (39)

AI tools can improve environmental sustainability in diagnostic imaging, examples including: (40)

- shorter scan times
- operational efficiency to switch power states between periods of high and low clinical use
- improved scheduling efficiency to reduce travel
- integration of clinical decision support tools to reduce low value imaging
- use AI tools to reduce the need for IV contrast

Research and education are needed to investigate and address strategies to minimize the environmental impact of AI and date use in radiology.

ENVIRONMENTAL SUSTAINABILITY AND AI IN RADIOLOGY: A DOUBLE-EDGE SWORD



Summary of how AI in Radiology has a negative impact on the environment, with key opportunities and actions to improve sustainability of AI in radiology
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About this playbook

LEAD AUTHORS

- Maura Brown MD, MHA, FRCPC
- Kate Hanneman MD MPH FRCPC

CAR WORKING GROUP CONTRIBUTORS

- Ania Keilar MD FRCPC
- Bruce B Forster MD FRCPC
- Brent Burbridge MD, FRCPC, Professor Emeritus
- Milad Hamwi MD
- Hayley McKee MD

CASCADES CONTRIBUTORS

- Sarah Machane, MSc, Innovation Lead (Quebec)
- Shugri Nour, RN, MN, Clinical Specialties Associate

GRAPHIC DESIGN

- Luz A. Paczka Giorgi

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