Canadian Association of Radiologists
L'Association canadienne des radiologistes

Canadian Association of Radiologists Statement on Environmental Sustainability in Medical Imaging

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Key Words

Climate change; environmental sustainability; diagnostic radiology; medical imaging; greenhouse gas emissions

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Disclosures

- KH: Co-Chair CAR Environmental Sustainability Working Group; Deputy Lead Sustainability, JDMI; Chair, ISMRM Environmental Sustainability Working Group; Member, RSNA Sustainability Task Force; Member, AUR Sustainability Committee; Associate Editor, Canadian Association of Radiologists Journal
- AH: Regional Department Head, Medical Imaging VCH and PHC; Vice-President, Canadian Association of Radiologists
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Background and Rationale

Immediate and strategic action is needed across sectors to improve environmental sustainability and reduce the detrimental effects of climate change. The predominant driver of climate change is human activities related to burning fossil fuels, which increase atmospheric greenhouse gas (GHG) levels, leading to rising global temperatures and disruption of climate and weather systems. A 2018 life cycle analysis estimated that Canada's healthcare system was responsible for 33 million tons of carbon dioxide equivalents (CO_2e) annually, accounting for 4.6% of the national total of GHG emissions [1].

Radiology contributes to the climate crisis by generating GHG emissions and waste during the production, manufacture, transportation, and use of medical imaging equipment and supplies [2–4]. A cross-sectional analysis of a single large Canadian hospital-based radiology department demonstrated substantial GHG emissions of 3235 tons CO_2e annually, equivalent to the energy consumed by 422 single-family homes [5]. Mitigation strategies to reduce GHG emissions and achieve net-zero, environmentally sustainable radiology departments are needed. At the same time, radiology departments must also build resiliency to current and future impacts of the climate crisis [6].

Climate change is already adversely affecting the health of Canadians related to worsening air pollution and wildfire smoke, increasing frequency and intensity of extreme weather events, and expansion of vector-borne and infectious illnesses [7]. These health effects result in higher health needs and healthcare utilization among the patients and populations served by medical imaging departments in Canada. Climate change affects everyone; however, vulnerable and disadvantaged individuals and groups are disproportionately affected due to health inequities [8].

Radiology departments are also 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 [9].

The Canadian Association of Radiologists' (CAR) advocacy for environmentally sustainable radiology in Canada encompasses both minimizing the detrimental effects that delivery of radiology services has on the environment and optimizing the resilience of radiology departments to increasing health needs and changing patterns of disease on imaging related to climate change (Figure 1). An overarching inclusive and integrated approach is needed to support environmentally sustainable radiology in Canada, inclusive of diverse perspectives and mindful of the linkages between social and environmental determinants of health.

This document was inspired by and modelled after the Canadian Medical Association's policy on Environmentally Sustainable Health Systems in Canada [10]. The CAR environmental sustainability statement provides specific recommendations and pathways to help guide radiologists, medical imaging leadership teams, industry partners, governments, and other key stakeholders to transition to environmentally sustainable, net-zero and climate-resilient radiology organizations. Specific consideration is given to unique aspects of medical imaging in Canada including the public payor system administered in each province and the vast geography with implications related to equitable access to medical imaging in rural and remote communities.

Environmentally sustainable radiology programs, policies, and achievements in Canada are highlighted including energy and cost-savings associated with powering down CT units when not in use in Vancouver (Figure 2) [11], unnecessary repeat imaging avoided with implementation of a provincial-wide clinical information and picture archiving and communication system in Alberta and other provinces (Figure 3) [12], implementation and evaluation of remotely controlled, robotic ultrasound in remote northern communities in Saskatchewan (Figure 4) [13], GHG emission and cost savings associated with implementation of portable low-field MRI in a remote Ontario community (Figure 5) [14], and energy and GHG emission savings associated with implementation of abbreviated MRI protocols in Toronto (Figure 6) [15]. However, further action is needed to achieve sustainable and climate-resilient radiology departments in Canada and to ensure a healthy and sustainable future for current and future generations.

Recommendations

To ensure an inclusive and integrated approach to building sustainable radiology departments, the CAR calls for:

Type of Action	Calls to Action
An inclusive and integrated approach to sustainable radiology *Refers to the lens we must apply when building sustainable radiology departments, inclusive of diverse perspectives and mindful of the linkages between social and environmental determinants of health*	▪ Governments to coordinate investments in health promotion, disease prevention, and early detection, including implementing and supporting imaging-based screening programs for breast cancer, coronary artery calcium, and CT colonography [6] ▪ Residency and fellowship training programs to incorporate training that addresses the symptoms and causes of climate-related health threats, as well as the health equity impacts on those who are disproportionately affected by climate change [16]

To achieve climate-resilient radiology departments, the CAR calls for:

Type of Action	Calls to Action
Medical imaging climate adaptation, resilience, and emergency preparedness	▪ Radiology departments to develop disaster management protocols to prepare for extreme weather events including potential work-force shortages and surges in imaging volumes [6]

Refers to minimizing radiology departments' vulnerability to climate-related impacts and climate-related emergencies by strengthening capacity and resiliency in the human and built environment	▪ Residency and fellowship training programs to incorporate climate adaptation into the curriculum to ensure future radiologists are prepared to appropriately diagnose climate-related illnesses [17,18] ▪ Professional societies and journals to provide education for practicing radiologists on climate change and changing disease patterns including expansion of vector borne illnesses and increased cardiovascular complications that may be identified on medical imaging [2,19] ▪ Hospitals and medical imaging departments to upgrade infrastructure to minimize damage to imaging departments and equipment in the event of flooding, storms, extreme temperatures, and power outages [6,20] ▪ Hospitals and medical imaging departments to ensure that information technology systems and data storage have redundancy and back-up power sources [6]

To achieve net-zero, environmentally sustainable radiology departments, the CAR calls for:

Type of Action	**Calls to Action**
Energy and greenhouse gas emission targets	▪ Government, regulators, and professional societies to develop sustainability related metrics and provide targets to reduce emissions for each imaging modality [21]

Refers to setting and developing a plan to achieve specific energy-use and GHG emission targets in radiology departments	▪ Vendors and industry partners to adhere to sustainability guidelines for reporting and GHG emissions reduction targets [22,23] ▪ Hospital and medical imaging administrators to develop organizational and departmental sustainability plans, define key performance indicators, set emissions reduction targets, and take actions to make their organizations more sustainable [6] ▪ Radiologists, technologists, and leadership teams to advocate for net-zero targets [24]
Environmentally sustainable medical imaging equipment *Refers to the reduction of energy intensity, associated GHG emissions and environmental impact of medical imaging equipment*	▪ Governments and regulators to define and mandate environmental performance and resilience standards for new and refurbished medical imaging equipment [25] ▪ Vendors and industry partners to develop medical imaging equipment with lower energy requirements and automated low power modes in idle and off states [6] ▪ Radiology departments to consider low-field MRI and other emerging medical imaging technology with lower energy and associated GHG emissions when appropriate [20] ▪ Funding organizations and professional societies to incentivize and fund development and implementation of medical imaging equipment with lower energy and GHG emissions [2]

Environmentally sustainable medical imaging policies and procedures *Refers to development of policies and procedures to reduce use-phase GHG emissions in radiology departments*	▪ Radiology departments to implement policies to reduce wasted energy including protocols to turn equipment off overnight and on the weekend when not in use [26] ▪ Radiology and hospital information technology teams to evaluate software to automatically power down computer workstations and other electronics when not in use in non-operational hours including overnight and weekends [27] ▪ Radiology departments and leadership teams to optimize scheduling of imaging to reduce idle time between examinations and increase overall utilization per imaging unit [28] ▪ Radiologists to abbreviate imaging protocols to reduce use-phase emissions per imaging examination [15] ▪ Radiology administrators to reduce energy use through changing energy use practices and investing in equipment such as motion sensor lighting and climate control systems [29] ▪ Radiology departments to optimize data storage and define policies for data retention and storage [30]
Environmentally sustainable purchasing in medical imaging	▪ Radiology departments and procurement teams to develop and implement sustainable procurement goals and strategies that increase the proportion of sustainable purchase orders and contracts [31]

Refers to reduction of upstream and downstream adverse environmental impacts of purchasing and procurement of in radiology infrastructure, equipment, and supplies	▪ Radiology departments and procurement teams to set targets to switch to reusable supplies from disposable supplies where feasible, to align with circular economy principles [2] ▪ Radiology departments and leadership team to include environmental sustainability in procurement evaluation criteria and requests for proposals (Scope 3) [2] ▪ Radiology leadership to engage hospital administration teams to invest in clean energy infrastructure rather than fossil fuel boilers (Scope 1) and advocate for purchase of electricity created by renewables rather than fossil fuels (Scope 2) [32]
Waste reduction in medical imaging *Refers to reduction or sustainable management of medical and non-medical waste in radiology*	▪ Radiology departments to collaborate with suppliers and health care providers to reduce waste by transitioning from single-use disposable products to reusable products, redesigning common interventional radiology procedure kits and improving disposal, reprocessing, and recycling methods for imaging products and supplies [33] ▪ Vendor partners and radiology departments to collaborate on development and implementation of programs for recycling unused contrast material including iodinated contrast and gadolinium-based contrast [34]

	▪ Radiology departments and hospitals to ensure that infrastructure is in place for recycling and composting of non-medical waste [35]
Sustainable transportation in medical imaging *Refers to reduction of air pollution and GHG emissions of transportation associated with medical imaging including patients and the workforce*	▪ Governments to collaborate with health authorities to reduce patient travel and improve health equity by providing local access to imaging services when feasible, particularly in northern, remote, rural, and Indigenous communities [13,36] ▪ Radiology departments to coordinate imaging with other healthcare appointments to minimize patient travel for multiple visits [37] ▪ Government, health systems, and radiology departments to promote, provide infrastructure for, and incentivize active and low-carbon transportation for patients, caregivers, and radiology team members [38] ▪ Governments to collaborate with health authorities to reduce regulatory barriers to remote radiologist interpretation of imaging studies, when appropriate

	▪ Relevant radiologists and departments to implement remote reporting when feasible, to reduce pollution and emissions related to radiologist transportation [39] ▪ Governments to finance zero-emission vehicle replacements for healthcare fleets, including vehicles used in the delivery of mobile imaging infrastructure to remote communities
Reduction of low-value and unnecessary medical imaging *Refers to reducing the adverse environmental impact of medical imaging services via resource stewardship while ensuring capacity to meet current and future medical imaging needs*	▪ Professional radiology societies, in collaboration with medical specialty societies and associations, to develop guidelines to Image Wisely and reduce unnecessary and excessive medical imaging [40] ▪ Governments to collaborate with health authorities to reduce unnecessary repeat imaging by developing information technology solutions to facilitate access to prior medical imaging examinations from outside centers [12] ▪ Governments to collaborate with health authorities to reduce unnecessary repeat imaging by providing incentives and reimbursement for radiologist second opinion interpretations of prior relevant imaging ▪ Radiologists and referring clinicians to adhere to appropriate use guidelines for initial and repeat imaging including follow-up of incidental findings [41]

	▪ Radiology departments and hospital information technology to automate clinical decision support tools in electronic health records to reduce unnecessary low-value imaging and align with appropriate use guidelines while ensuring capacity to meet current and future medical imaging needs [42] ▪ Medical, residency, and fellowship training programs to incorporate education on low-value imaging and appropriate use criteria
Sustainable resources and environmental contamination *Refers to reducing the reliance on finite resources and reduction of GHG emissions and environmental contamination related to radiology equipment and supplies*	▪ Governments to anticipate challenges to medical device, helium, contrast media, and other supply chains as a result of national and international climate disruption, and to ensure institutional purchasing is coordinated with decarbonization efforts to increase use of reusable items where appropriate, recycle and reuse supplies when feasible, maximize value through bulk purchasing when feasible [43] ▪ Radiologists and radiology departments to reduce waste and environmental waterbody contamination of CT and MRI contrast media by switching from single use to multi-patient dose contrast delivery systems [44] ▪ Radiologists and radiology departments to reduce unnecessary utilization of CT and MRI contrast media through implementation of low- or no-contrast protocols

	and virtual contrast enhanced imaging when appropriate [23] ▪ Radiologists and radiology departments to implement policies to guide appropriate use of ultrasound-enhancing agents and provide education on their direct environmental impact as fluorinated gases with high global warming potentials [45] ▪ Radiologists and radiology departments to implement policies to reduce the environmental impact of administered radiopharmaceuticals and minimize radioactive waste in nuclear medical imaging [46] ▪ Vendors, radiologists, and procurement teams to develop and prioritize low- or no-helium MRI systems and processes to recycle and recapture helium used for cooling [20] ▪ Radiology departments to promote sustainable anesthetic practices such as eliminating desflurane use and installing anesthetic gas capture and reuse systems when anaesthesia is required in medical imaging [47]
Environmentally sustainable development and use of technology in radiology	▪ Radiology departments, industry, and health authorities to collaborate on the implementation and evaluation of mobile imaging solutions to reduce patient travel and increase imaging access to imaging in rural and remote communities, such as robotic ultrasound and mobile MRI [14,48]

Refers to innovation, development, and implementation of environmentally sustainable medical imaging technology including mobile and robotic imaging	▪ Radiology departments to evaluate potential trade-offs with mobile imaging with respect to reduced emissions related to patient travel but potentially higher emissions related to operation and transport of mobile imaging equipment and teams [13] ▪ Governments, health authorities, and radiology departments to develop standards for remote scanning by technologists to reduce the need for patient and technologist travel to and from remote areas, including capacity for real time remote supervision by radiologists when appropriate ▪ Vendors, radiologists, and scientists to collaborate on development, evaluation, and implementation of artificial intelligence (AI)-tools to improve sustainability in radiology and evaluate trade-offs with respect to the energy and GHG emissions required to develop AI models [23]

References

1. Eckelman MJ, Sherman JD, MacNeill AJ. Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis. *PLoS Med*. 2018;15(7):e1002623. doi:10.1371/journal.pmed.1002623

2. Brown M, Schoen JH, Gross J, Omary RA, Hanneman K. Climate Change and Radiology: Impetus for Change and a Toolkit for Action. *Radiology*. Published online 2023:230229. doi:10.1148/radiol.230229

3. Picano E, Mangia C, D'Andrea A. Climate Change, Carbon Dioxide Emissions, and Medical Imaging Contribution. *J Clin Medicine*. 2022;12(1):215. doi:10.3390/jcm12010215

4. Kouropoulos G. A predictive model for the estimation of carbon dioxide emissions of magnetic resonance imaging units and computed tomography scanners. *J Urban Environ Eng*. Published online 2019:172-187. doi:10.4090/juee.2018.v12n2.172-187

5. Hanneman K, McKee H, Nguyen ET, Panet H, Kielar A. Greenhouse Gas Emissions by Diagnostic Imaging Modality in a Hospital-Based Radiology Department. *Canadian Association of Radiologists Journal*. 2024;Accepted, in press.

6. McKee, Brown M, Kim H, et al. Planetary Health and Radiology: Why we should care and what we can do. *Radiology*. 2024;Accepted, in press.

7. The Intergovernmental Panel on Climate Change (IPCC). Common enabling factors and constraints for adaptation and mitigation responses. Published 2024. Accessed February 25, 2024. https://ar5-syr.ipcc.ch/topic_adaptation.php

8. Friel S, Arthur M, Frank N. Power and the planetary health equity crisis. *Lancet*. 2022;400(10358):1085-1087. doi:10.1016/s0140-6736(22)01544-6

9. Bluth EI, Kay D, Smetherman D, et al. Managing in a catastrophe: radiology during Hurricane Katrina. *AJR Am J Roentgenol*. 2007;188(3):630-632. doi:10.2214/ajr.06.1464

10. Canadian Medical Association. Environmentally Sustainable Health Systems in Canada. Published 2022. Accessed April 1, 2024. https://policybase.cma.ca/viewer?file=%2Fmedia%2FPolicyPDF%2FPD23-02.pdf#page=1

11. Brown M, Snelling E, Alba MD, Ebrahimi G, Forster BB. Quantitative Assessment of Computed Tomography Energy Use and Cost Savings Through Overnight and Weekend Power Down in a Radiology Department. *Can Assoc Radiologists J*. Published online 2022:084653712211330. doi:10.1177/08465371221133074

12. Sutton RT, Dhillon-Chattha P, Kumagai J, Pitamber T, Meurer DP. System Configuration Evaluation for a Province-Wide Clinical Information System Using the eSafety Checklist. *Appl Clin Inform*. 2023;14(04):735-742. doi:10.1055/s-0043-1771392

13. Adams SJ, Burbridge B, Chatterson L, Babyn P, Mendez I. A Telerobotic Ultrasound Clinic Model of Ultrasound Service Delivery to Improve Access to Imaging in Rural and Remote Communities. *J Am Coll Radiol*. 2022;19(1):162-171. doi:10.1016/j.jacr.2021.07.023

14. DesRoche CN, Johnson AP, Hore EB, et al. Feasibility and Cost Analysis of Portable MRI Implementation in a Remote Setting in Canada. *Can J Neurol Sci J Can des Sci Neurol*. Published online 2023:1-10. doi:10.1017/cjn.2023.250

15. Ibrahim F, Cadour F, Washburn AC, et al. Energy and Greenhouse Gas Emission Savings Associated with Implementation of an Abbreviated Cardiac MRI Protocol. *Radiology*. 2024:Accepted, in press.

16. Deivanayagam TA, English S, Hickel J, et al. Envisioning environmental equity: climate change, health, and racial justice. *Lancet (Lond, Engl)*. 2023;402(10395):64-78. doi:10.1016/s0140-6736(23)00919-4

17. Green S, Labine N, Luo OD, et al. Planetary Health in CanMEDS 2025. *Can Méd Educ J*. 2023;14(1):46-49. doi:10.36834/cmej.75438

18. Arepally A, Omary RA, Vandenbergh MP. Scanning the Planet: Radiology's Grand Opportunity to Address Climate Change. *J Am Coll Radiol*. 2022;19(1):217-219. doi:10.1016/j.jacr.2021.08.031

19. Confalonieri UE, Menezes JA, Souza CM de. Climate change and adaptation of the health sector: The case of infectious diseases. *Virulence*. 2015;6(6):554-557. doi:10.1080/21505594.2015.1023985

20. Chaban YV, Vosshenrich J, McKee H, et al. Environmental Sustainability and MRI: Challenges, Opportunities, and a Call for Action. *J Magn Reson Imaging*. Published online 2023. doi:10.1002/jmri.28994

21. Hanneman K, Araujo-Filho JAB, Nomura CH, Jakubisin J, Moy L. Climate Change and Sustainability. *Radiology*. 2023;307(4):e230903. doi:10.1148/radiol.230903

22. US Government ENERGY STAR. ENERGY STAR® Program Requirements Product Specification for Medical Imaging Equipment. Published 2024. Accessed April 4, 2024. https://www.energystar.gov/products/spec/medical_imaging_equipment_version_1_0_pd

23. Doo FX, Vosshenrich J, Cook TS, et al. Environmental Sustainability and AI in Radiology: A Double-Edged Sword. *Radiology*. 2024;(310). doi:10.1148/radiol.232030

24. Canadian Medical Association. Why Canada needs a net-zero health system. Published 2024. Accessed April 1, 2024. https://www.cma.ca/our-focus/net-zero-emissions-health-system/why-canada-needs-net-zero-health-system

25. International Electrotechnical Commission. Good refurbishment practices for medical imaging equipment. IEC 63077 ED1. Published online 2019. https://webstore.iec.ch/publication/61821

26. Woolen SA, Becker AE, Martin AJ, et al. Ecodesign and Operational Strategies to Reduce the Carbon Footprint of MRI for Energy Cost Savings. *Radiology*. 2023;307(4):e230441. doi:10.1148/radiol.230441

27. Data Synergy. PowerMAN reduces NHS Hospital IT energy costs. Published 2023. Accessed January 15, 2024. https://www.datasynergy.co.uk/casestudies/sthnhs.aspx

28. Esmaeili A, McGuire C, Overcash M, Ali K, Soltani S, Twomey J. Environmental impact reduction as a new dimension for quality measurement of healthcare services. *Int J Heal Care Qual Assur*. 2018;31(8):910-922. doi:10.1108/ijhcqa-10-2016-0153

29. MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. *Lancet Planet Heal*. 2017;1(9):e381-e388. doi:10.1016/s2542-5196(17)30162-6

30. Doo FX, Kulkarni P, Siegel E, et al. Economic and environmental costs of cloud for medical imaging and radiology artificial intelligence. *J Am Coll Radiol*. Published online 2023. doi:10.1016/j.jacr.2023.11.011

31. Delre A, Placa ML, Alfieri F, et al. Assessment of the European Union Green Public Procurement criteria for four product groups. Published 2022. Accessed April 1, 2024. https://publications.jrc.ec.europa.eu/repository/handle/JRC127215

32. GE Energy. National Renewable Energy Lab. Western Wind and Solar Integration Study. Published online 2010. doi:10.2172/981991

33. Thiel CL, Woods NC, Bilec MM. Strategies to Reduce Greenhouse Gas Emissions from Laparoscopic Surgery. *Am J Public Health*. 2018;108(S2):S158-S164. doi:10.2105/ajph.2018.304397

34. Dekker HM, Stroomberg GJ, Prokop M. Tackling the increasing contamination of the water supply by iodinated contrast media. *Insights Imaging*. 2022;13(1):30. doi:10.1186/s13244-022-01175-x

35. Azmal M, Kalhor R, Dehcheshmeh NF, Goharinezhad S, Heidari ZA, Farzianpour F. Going toward Green Hospital by Sustainable Healthcare Waste Management: Segregation, Treatment and Safe Disposal. *Health*. 2014;06(19):2632-2640. doi:10.4236/health.2014.619302

36. Davidson M, Kielar A, Tonseth RP, Seland K, Harvie S, Hanneman K. The Landscape of Rural and Remote Radiology in Canada: Opportunities and Challenges. *Can Assoc Radiol J*. Published online 2023:8465371231197953. doi:10.1177/08465371231197953

37. Patel KB, Gonzalez BD, Turner K, et al. Estimated Carbon Emissions Savings With Shifts From In-Person Visits to Telemedicine for Patients With Cancer. *JAMA Netw Open*. 2023;6(1):e2253788. doi:10.1001/jamanetworkopen.2022.53788

38. Practice Greenhealth. Employee Commute Single Occupancy Vehicle Rate Reduction. Employee Commute Single Occupancy Vehicle Rate Reduction. Published 2020. Accessed January 1, 2024. https://practicegreenhealth.org/sites/default/files/upload-files/case_studies/seattle_childrens_-_employee_commute_case_study.pdf

39. Morissette R, Deng Z, Messacar D. Working from home: Potential implications for public transit and greenhouse gas emissions. Published 2021. Accessed January 3, 2023. https://www150.statcan.gc.ca/n1/pub/36-28-0001/2021004/article/00005-eng.htm

40. Alshqaqeeq F, McGuire C, Overcash M, Ali K, Twomey J. Choosing radiology imaging modalities to meet patient needs with lower environmental impact. *Resour, Conserv Recycl*. 2020;155:104657. doi:10.1016/j.resconrec.2019.104657

41. Davenport MS. Incidental Findings and Low-Value Care. *AJR Am J Roentgenol*. 2023;221(1):117-123. doi:10.2214/ajr.22.28926

42. Kjelle E, Andersen ER, Krokeide AM, et al. Characterizing and quantifying low-value diagnostic imaging internationally: a scoping review. *Bmc Med Imaging*. 2022;22(1):73. doi:10.1186/s12880-022-00798-2

43. Grist TM, Canon CL, Fishman EK, Kohi MP, Mossa-Basha M. Short-, Mid-, and Long-Term Strategies to Manage the Shortage of Iohexol. *Radiology*. 2022;304(2):289-293. doi:10.1148/radiol.221183

44. Lindsey JS, Frederick-Dyer K, Carr JJ, Cooke E, Allen LM, Omary RA. Modeling the Environmental and Financial Impact of Multi-dose vs. Single-dose Iodinated Contrast Media Packaging and Delivery Systems. *Acad Radiol*. Published online 2023. doi:10.1016/j.acra.2022.12.029

45. Kang HJ, Lee JM, Yoon JH, Lee K, Kim H, Han JK. Contrast-enhanced US with Sulfur Hexafluoride and Perfluorobutane for the Diagnosis of Hepatocellular Carcinoma in Individuals with High Risk. *Radiology*. 2020;297(1):209017. doi:10.1148/radiol.2020209017

46. Aisyah, Artiani PA, Rachmadetin J. Radioactive Fission Waste from Molybdenum-99 Production and Proliferation Risks. *IOP Conf Ser: Earth Environ Sci*. 2021;927(1). doi:10.1088/1755-1315/927/1/012041

47. Devlin-Hegedus JA, McGain F, Harris RD, Sherman JD. Action guidance for addressing pollution from inhalational anaesthetics. *Anaesthesia*. 2022;77(9):1023-1029. doi:10.1111/anae.15785

48. Adams SJ, Penz E, Imeah B, et al. Economic Evaluation of Telerobotic Ultrasound Technology to Remotely Provide Ultrasound Services in Rural and Remote Communities. *J Ultrasound Med*. 2023;42(1):109-123. doi:10.1002/jum.16070

Figures

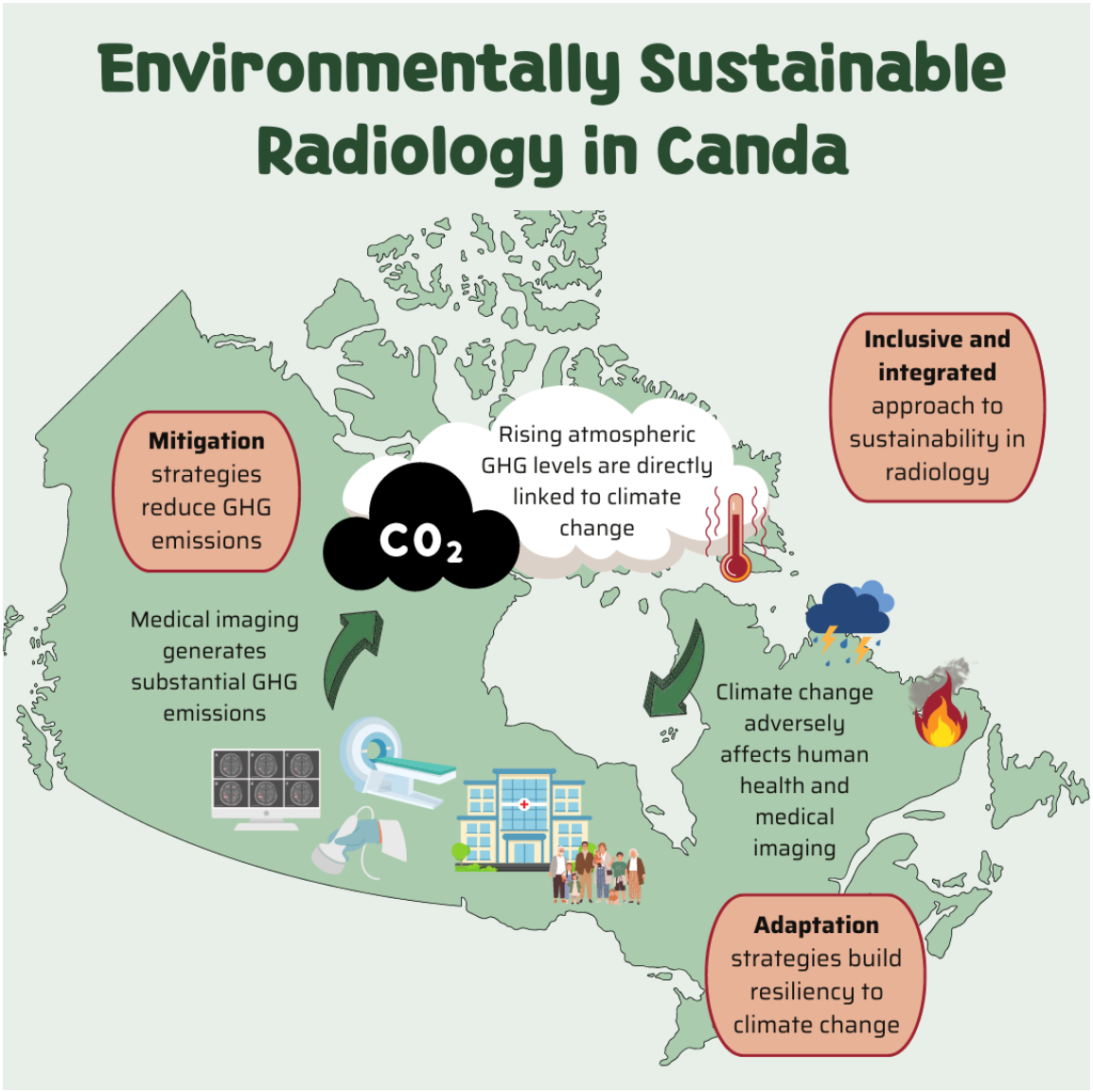

Figure 1. Interconnected relationship between radiology, climate change, and environmental sustainability in Canada. Mitigation strategies reduce greenhouse gas (GHG) emissions. Adaptation strategies build resiliency to current and future impacts of the climate crisis. An inclusive and integrated approach is needed to support environmentally sustainable radiology, inclusive of diverse perspectives and mindful of the linkages between social and environmental determinants of health.

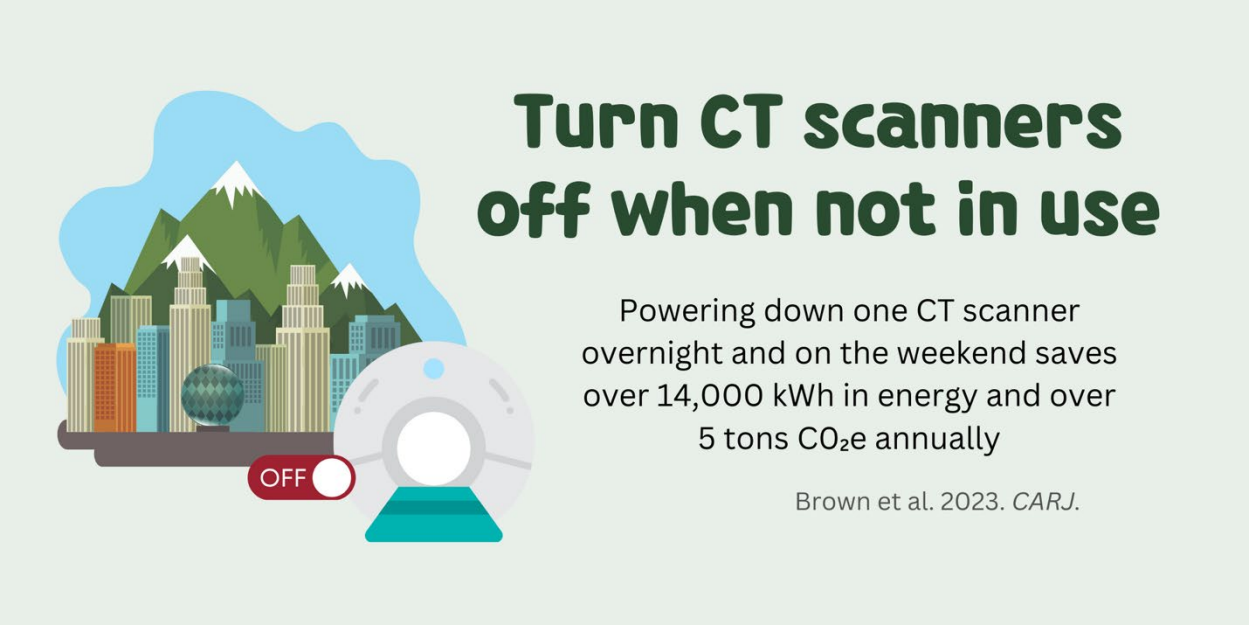

Figure 2. Energy and cost-savings associated with powering down CT units when not in use.[11]

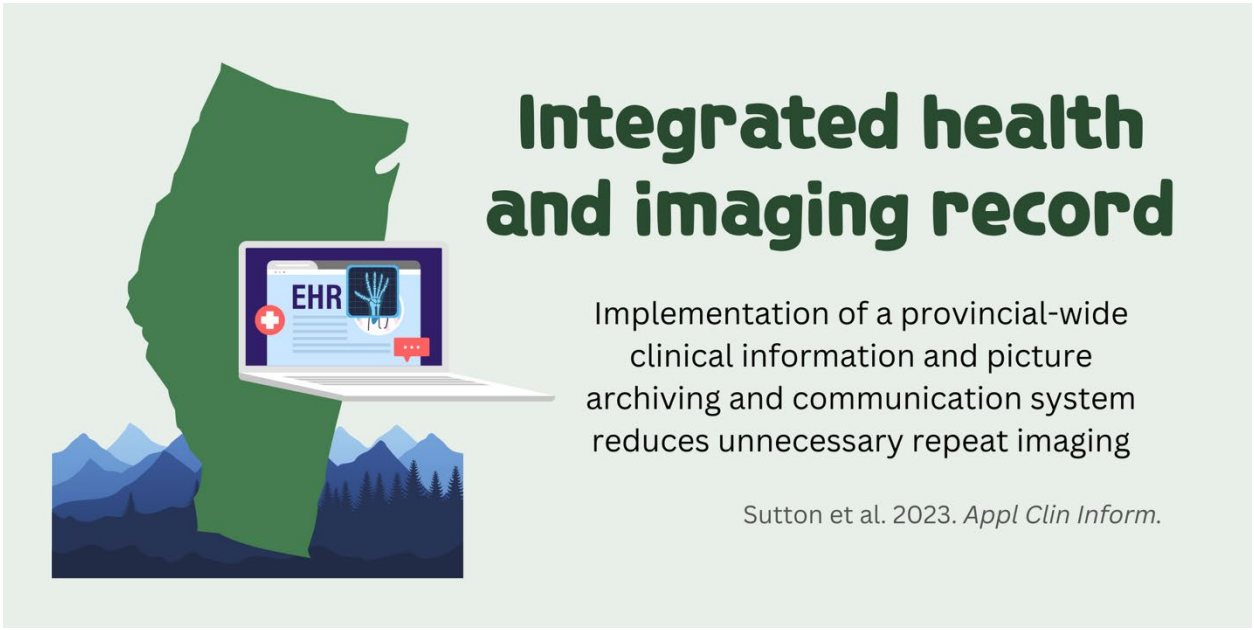

Figure 3. Integrated provincial-wide clinical information and picture archiving and communication system can reduce the need for repeat imaging and associated greenhouse gas emissions.[12]

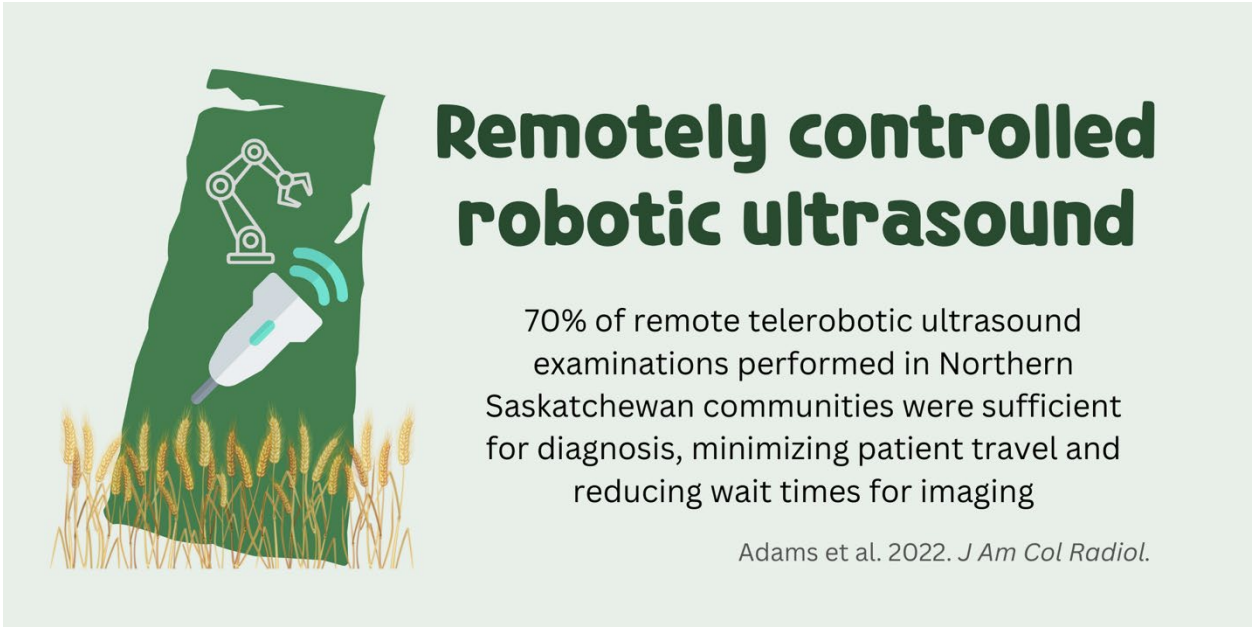

Figure 4. Remotely controlled robotic ultrasound can potentially reduce patient travel and greenhouse gas emissions while improving access to medical imaging.[13]

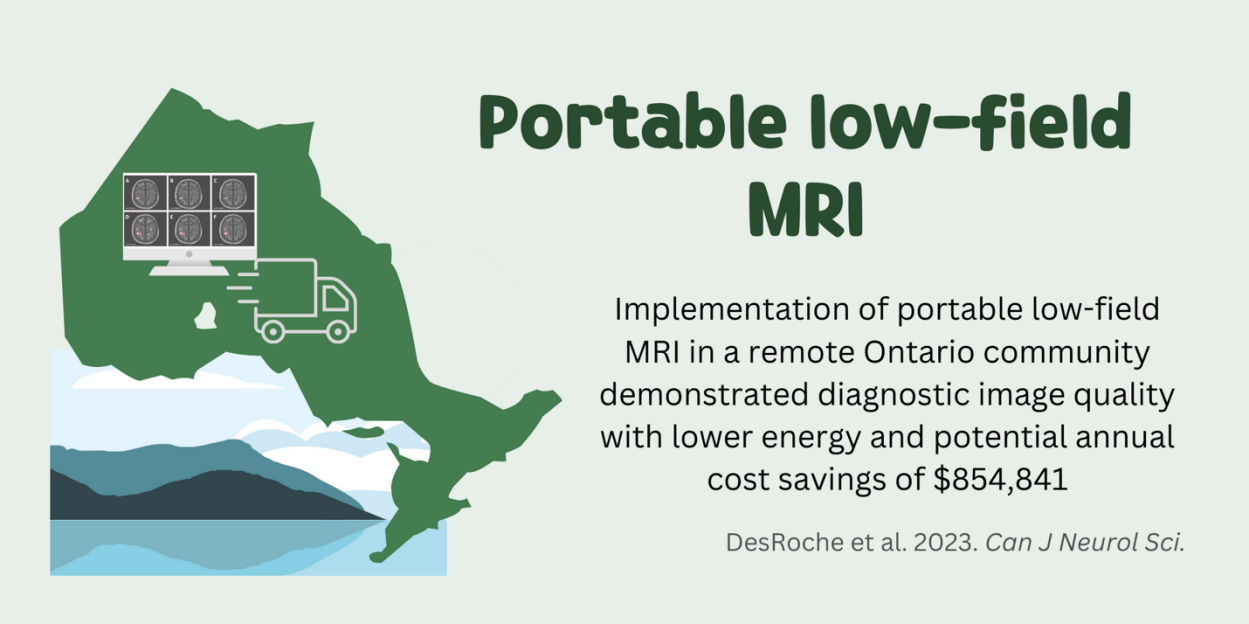

Figure 5. Portable low-field MRI can potentially avoid greenhouse gas emissions associated with patient and radiologist travel and reduce cost.[14]

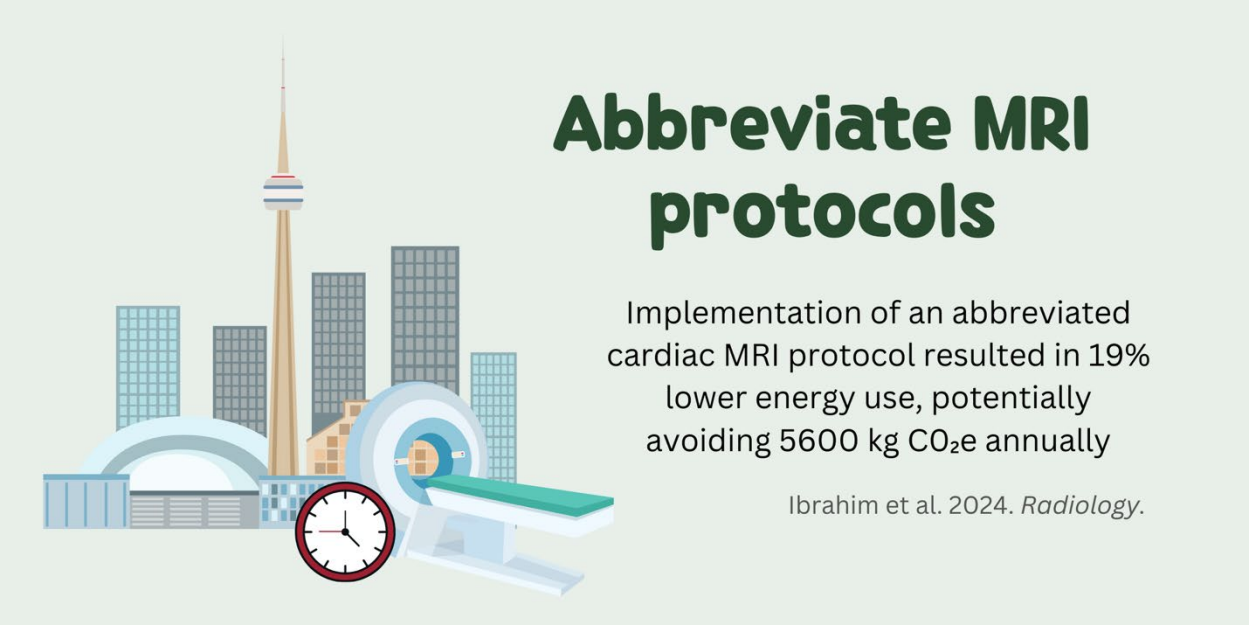

Figure 6. Implementation of an abbreviated cardiac MRI protocol reduces time, energy use, and greenhouse gas emissions.[15]