Radiology

REVIEWS AND COMMENTARY • SPECIAL REPORT

Climate Change and Radiology: Impetus for Change and a Toolkit for Action

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This special report discusses the importance of climate change for health care and radiology. The impact of climate change on human health and health equity, the contribution of health care and medical imaging to the climate crisis, and the impetus for change within radiology to create a more sustainable future are covered. The authors focus on actions and opportunities to address climate change in our role as radiologists. A toolkit highlights actions we can take toward a more sustainable future, linking each action with the expected impact and outcome. This toolkit includes a hierarchy of actions from first steps to advocating for system-level change. This includes actions we can take in our daily lives, in radiology departments and professional organizations, and in our relationships with vendors and industry partners. As radiologists, we are adept at managing rapid technological change, which makes us ideally suited to lead these initiatives. Alignment of incentives and synergies with health systems are highlighted given that many of the proposed strategies also result in cost savings.

Supplemental material is available for this article.

Climate change refers to long-term changes in weather patterns and temperature. It occurs due to increasing CO_2 and other greenhouse gases (GHGs) in the upper atmosphere of Earth. Planetary health is a more recent term that references the understanding that long-term human health depends on the well-being of our planet, including living and nonliving systems (1,2). Human activity, primarily the burning of fossil fuels (coal, oil, and gas), has increased atmospheric levels of GHGs. These gases absorb and trap heat, creating an energy imbalance that increases temperatures on Earth.

This special report addresses the importance of climate change to radiologists and the medical imaging community, including the impact on human health and health equity, the contribution of health care and medical imaging to the climate crisis, and the impetus to build a more sustainable future. The article is focused on actions and opportunities to address climate change in our role as radiologists and to link our actions with their impact and expected outcomes. Radiologists are adept at managing rapid technological change. Thus, radiologists are ideally suited to lead these initiatives within our departments, health care systems, and communities.

Impact of Climate Change on Human Health and Health Equity

The health harms of climate change disproportionately affect those already vulnerable due to social, environmental, and public health factors. Groups most likely to be harmed are those already experiencing health inequities due to age, race and ethnicity, culture, sex and gender, socioeconomic status, geographic location, and chronic illness. As the energy imbalance of Earth worsens and global temperature increases, extremes of weather that include storms, floods, and heat domes will become more frequent and severe. Warm air holds more water, leading to increased precipitation and flooding in parts of the globe. In other geographic regions, disturbed precipitation patterns will lead to drought and food insecurity, longer and more intense wildfire seasons, and acidification of the ocean with associated negative impacts on marine ecosystems (3). Adverse impacts of climate change on human health are highlighted in Figure 1.

Extreme heat increases heat stroke and heat exhaustion and exacerbates underlying cardiovascular and kidney diseases (4). Children and older adults, those on certain medications such as diuretics and antipsychotics, and those working outdoors are more vulnerable. Extreme weather events, including hurricanes and flooding, harm health through physical injury, displacement, and waterborne illness. These events most severely impact those who are underhoused and resource poor, with the least means to recover. Poor air quality due to local air pollution from combustion of fossil fuels, as well as wildfire smoke, harms health through inhalation of fine particulates, carbon monoxide, ground-level ozone, nitrogen dioxide, and sulfur dioxide (5). Specific diseases strongly linked to air pollution include stroke, ischemic heart disease, asthma, chronic obstructive pulmonary disease (COPD), lung cancer, and pneumonia.

Abbreviations

GHG = greenhouse gas, PACS = picture archiving and communication system

Summary

As global health care transforms to a low-carbon sustainable future, radiologists have a responsibility to lead change at work, at home, and in our communities.

Essentials

- Climate change is already affecting human health, with disproportionate effects on vulnerable populations.
- The health care system, including the field of radiology, is a substantial contributor to greenhouse gas emissions.
- Actions we can take now have the potential for substantial energy savings, and radiologists are ideally positioned to lead these initiatives at work, at home, and in our communities.

The geography of vector-borne illnesses is changing, including Lyme disease and West Nile virus. Food security and food quality are also threatened by climate change. Drought and extreme weather events impact crop yields, and elevated atmospheric CO_2 is associated with reduced nutritional quality for many staple food crops (6). Mental health effects include posttraumatic stress disorder, increased interpersonal violence, and climate anxiety about the future.

Contribution of Health Care and Radiology to Climate Change

The increased incidence of disease, famine, conflict, and vector-borne illnesses caused by climate change is expected to cause an additional 250 000 deaths per year between 2030 and 2050 from malnutrition, malaria, diarrhea, and heat stress alone (7). However, the overall impact of climate change may be larger. A recent analysis estimated that nonoptimal temperatures are associated with more than 5 million deaths per year globally (8). Ironically, the health care system—which must respond to this grave public health crisis—emits substantial volumes of GHGs and is an important driver of climate change.

Due to its large size and its intensive use of resources, the global health care system emits more than 2 gigatons of CO_2 equivalent (CO_2e) annually and accounts for 5%–8.5% of total GHG emissions in developed nations (9). If the global health care system were a country, it would be the fifth largest emitter of GHGs on the planet (10–12). The volumes of GHGs emitted by health care systems of different countries vary greatly. The health care systems of wealthier countries contribute disproportionately both in terms of absolute volumes of GHGs emitted and per capita emissions. For example, the U.S. health care system accounts for 27% of total emissions from the global health care system and contributes to the loss of approximately 388 000 disability-adjusted life-years (DALY) annually (9,13). One DALY represents the loss of 1 year of full health due to disability, ill health, or early death.

While the majority of GHGs emitted by the health care sector come from manufacturing, transporting, using, and disposing of purchased goods, the sources of emissions from individual specialties differ. For diagnostic radiology, most emissions come from the production of medical imaging equipment and the energy needed to power it. Overall, medical imaging is estimated to account for 1% of global GHG emissions (14). Emissions are much higher from MRI than from CT, which in turn are far greater than those from US (15). These differences are largely driven by varying energy consumption for each type of imaging equipment.

For example, a single MRI study of the abdomen uses enough energy to cool a three-bedroom home for an entire day and generates GHG emissions equivalent to driving a motor vehicle 180 miles (15). At a Swiss hospital, the energy to power four MRI and three CT scanners over the course of 1 year, with their associated cooling systems, was equivalent to that required to power a town of 852 people and cost approximately \$200 000 (16). Much of this energy was used inefficiently when the equipment was not in active use (approximately two-thirds for CT and one-third for MRI).

While they consume less energy than imaging equipment, computer workstations are another important source of GHG emissions in radiology departments. One study found that 32 workstations in one department consumed enough energy to power 12 family homes (17). Most energy was consumed when the workstations were not being used. Another study found that computers and picture archiving and communication system (PACS) stations left on at night and on weekends in a radiology department generated GHG emissions similar to the annual emissions from 10 vehicles (18).

Unlike diagnostic radiology, where emissions are driven largely by energy used to power imaging equipment and electronic hardware, the largest source of GHG emissions from interventional radiology (IR) is the energy needed to maintain temperature and humidity in the IR suite. A life cycle assessment performed in the IR department at an academic hospital found that the department generated 23 500 kg of CO_2 equivalent over 5 days—equivalent to emissions from driving a motor vehicle approximately 59 000 miles (19). The leading source of emissions was the energy used to maintain climate control, followed by emissions related to the production and transportation of single-use surgical supplies. In that study, 57% of the energy used to power the climate control system occurred outside of working hours when the IR suite was not in use. Thus, occupancy sensors in the IR suite might reduce emissions related to climate control.

Climate-sensitive extreme weather events can negatively impact health care access and increase the financial burden for institutions (20). For example, the NYU Langone Health System lost approximately \$1.4 billion in revenue after Hurricane Sandy (21). In addition to overwhelming local health care systems from mass casualties, extreme weather can damage infrastructure and disrupt communication systems, including PACS. Unpredictable weather can also impact transportation, leading to delays and cancellations, potentially affecting travel to medical conferences as well as patient no-shows (22).

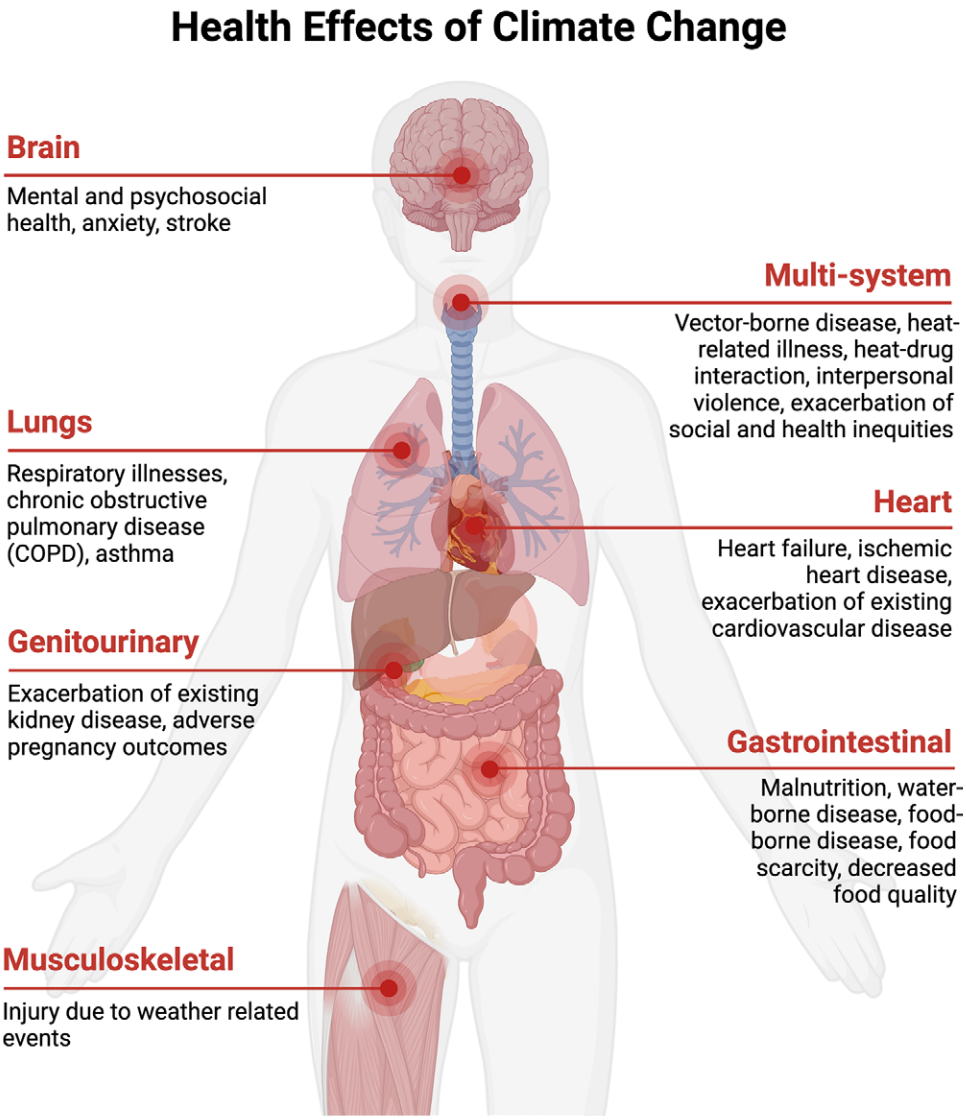

Figure 1: Illustration shows the health effects of climate change grouped according to organ system. Created with BioRender.com.

Impetus to Address Climate Change and Barriers to Action

Although the existential dangers of climate change have been known for decades, the health care system has been slow to address its substantial carbon footprint. At the institutional level, this lack of urgency may be explained by ignorance about the contribution of health care to climate change, the financial costs of change, and the lack of incentives. For individuals, there are myriad economic, social, educational, and political reasons. Psychologic reasons include denial or a sense of futility, hope in future technologies, a perception that the climate crisis is distant in time, and the tendency to prioritize short-term convenience over long-term interests (23,24).

Whatever the reasons for historic inaction, there is a growing movement to align the environmental practices of health care with its core mission to minimize harm and protect public health. The National Health Service in the United Kingdom plans to achieve net zero emissions by 2040, and more than 100 health care systems have joined the U.S. Department of Health and Human Services pledge to reduce carbon emissions by 50% before the end of this decade and to achieve net zero emissions by 2050 (25,26). By investing in renewable energy, green building construction, and carbon offsets, Kaiser Permanente, which is the largest integrated health system in the United States, achieved net zero emissions in 2020 (27). Sustainability is being incorporated into medical society guidelines and consensus statements, medical education, and individual practices. Research into the environmental impact of individual medical specialties is growing (28,29). Importantly, patients also expect change to address the climate crisis. In a United Kingdom survey, 92% of patients reported it was important for health care systems to operate more sustainably (30). Figure 2 highlights key reasons that radiologists should care about climate change.

As the focus on sustainability increases, radiologists are well positioned to play a leading role in advocating for greener health care. Radiologists routinely interact with colleagues across medical specialties and can capitalize on their wide social networks to educate others about the need for change. Key principles for communicating about climate change include simple messages, repeated often, by a variety of trusted sources (24). As experts in technology, radiologists can innovate more sustainable methods of care, such as finding new applications for telemedicine and telecommuting, reducing energy-intense imaging sequences that do not add clinical value, and scheduling patients more efficiently to minimize idle time for equipment. As key players in the purchasing process, radiologists can prioritize the energy efficiency of equipment in their purchasing decisions and pressure vendors to improve the sustainability of their products.

A framework for environmentally sustainable health systems can be applied in radiology departments (31). First, reduce demand for health care services by supporting policies and programs that promote public health, including screening. Second, match the supply of health services to the demand; for example, by ensuring the appropriate use of imaging. Finally, reduce emissions from the provision of necessary care.

The U.S. Environmental Protection Agency scoping system for GHG emissions is used by many hospital systems and

Why Should Radiologists Care About Climate Change?

	Reason
Near-term impact and health equity	Climate change negatively impacts human health now
	Vulnerable populations are disproportionately affected
	Extreme weather events disrupt the health system's ability to deliver care
Impact of health care and radiology	The health care sector is responsible for a large amount of GHG emissions
	Radiology is a major contributor due to high energy consumption and waste
	Patients expect health care systems to operate more sustainably
Potential for change	We can protect public health and those most vulnerable to climate change
	Actions we can take now have the potential for substantial energy savings
	Radiologists are ideally positioned to lead change for sustainable healthcare

Figure 2: Chart shows key reasons radiologists should care about climate change. GHG = greenhouse gas. Created with BioRender.com.

is useful for comparisons and tracking over time. Scope 1 (direct) emissions are generated directly by an organization (including heating and climate control), scope 2 (indirect) emissions are from purchased energy (primarily electricity), and scope 3 (indirect) are all other indirect emissions from sources not owned or controlled by the organization (including production, transport, and disposal of medical devices and supplies) (13). Scope 3 is usually the largest source of GHG emissions in health care.

Actions and Opportunities to Address Climate Change

The top actions we can take to address climate change are highlighted in Figure 3, along with their impact. Individuals and institutions can start with one or two smaller changes and build from there.

Top 10 Actions to Address Climate Change

	Action	Impact
Daily Lives	① Increase plant-forward meals and reduce waste	20-30% reduction of GHG emissions by halving meat consumption
	② Use alternative modes of transportation	67% decrease in GHG emissions from transport by shifting one car trip to one bike trip per day
	③ Shift toward building electrification	38-53% reduction in C02 emissions for a residential heat pump over a gas furnace
Radiology Departments	④ Turn off electronics and CT scanners overnight	40-80% energy saving by powering down CT scanners during non-operations time
	⑤ Limit single-use disposable medical supplies	41% of total GHG emissions in interventional radiology suites
	⑥ Reduce low-value imaging	$433 million cost savings yearly with appropriate use guidelines
	⑦ Reduce waste of contrast and single-use plastic	93% reduction in plastic waste by switching to multi-dose contrast system
Industry and Vendors	⑧ Implement sustainable procurement policies	50-80% potential energy savings
	⑨ Improve energy consumption in idle and system-off states	30-67% energy consumption for CT and MRI in non-productive modes
	⑩ Decrease packaging of medical supplies	Less waste and lower energy and cost from transportation

Figure 3: Chart shows the top 10 actions for radiologists to address climate change. GHG = greenhouse gas. Created with BioRender.com.

Table 1: Actions to Address Climate Change in Our Daily Lives

Action	Rationale	Outcome
Shift toward a plant-forward diet	Meat and dairy food production accounts for 15% of global GHG emissions. The climate impact of plant-based foods is approximately 10–50 times less than that of animal products (32).	A 20%–30% reduction of GHG emissions per person is achieved by halving meat consumption (34). A 49% reduction overall in diet-related GHG emissions occurs from transitioning to a plant-based diet (decrease of 6.6 billion metric tons of CO_2 globally) (33).
Reduce food waste	35% of all food in the United States went unsold or uneaten in 2019 (equivalent to 4% of total U.S. GHG emissions) (54).	A 6%–8% reduction of GHG emissions is achieved if food waste is stopped (55).
Use alternative modes of transportation	Transportation accounts for 27% of total U.S. GHG emissions (the largest contributor nationally) (35).	A 67% reduction of GHG emissions from transport for the average person is managed by shifting one car trip to one bike trip per day (56). Sustainable transportation also results in less air and noise pollution.
Choose the least-polluting and most-efficient vehicle	Burning 1 gallon of gasoline creates approximately 20 pounds of CO_2, and the average vehicle creates 6–9 tons of CO_2 each year (36).	Switching from a vehicle that has 20 mpg to a vehicle that has 25 mpg reduces GHG emissions by 1.7 tons annually (36).
Reduce air travel	Air travel contributes approximately 7% of the total anthropogenic greenhouse effect.	Avoiding one transatlantic trip by air is equivalent to going gasoline car–free for a year, saving more than 1500 kg of CO_2 (37).
Building electrification (shift to electricity rather than fossil fuels)	Residential energy use for heating, cooling, and powering households accounts for 20% of GHG emissions in the United States (38).	A 38%–53% reduction in CO_2 emissions is possible by switching to a residential heat pump rather than a gas furnace (57). An additional benefit is healthier indoor air.
Switch to LED lighting	Lighting accounts for 5% of global CO_2 emissions. This is one of the most ready-to-implement technologies to address climate change.	A 50%–70% energy savings occurs by switching from fluorescent lights to LED lights. A global switch to LED technology can save 1400 million tons of CO_2 (58).
Get involved in local or national advocacy	Carbon emissions from health care are related to the carbon intensity of the grid, with higher GHG emissions in regions where fossil fuels dominate the energy mix (15,21).	A 39% reduction in health care emissions can occur by switching to renewable power sources, which will involve changes at the municipal and local level (59).

Note.—GHG = greenhouse gas, LED = light-emitting diode.

Toolkit for Action in Our Daily Lives

There are many steps that radiologists can take to reduce their personal carbon footprint, as outlined in Table 1. The highest impact decisions we make in our daily lives include what we eat, how we move around, and how we heat our buildings.

Food production accounts for 25% of global GHG emissions, with 15% of the total due to the meat and dairy industries (32). Shifting to plant-forward diets has the potential for a massive impact by reducing food-related land use by 76% and GHG emissions by 49% (33). Even halving meat consumption reduces GHG emissions by 20%–30% (34).

Transportation is the largest contributor in the United States, accounting for 27% of total national GHG emissions (35). Alternate modes of transportation, such as cycling and public transportation, reduce air pollution with additional benefits that include improved cardiorespiratory health. When personal transportation is necessary, individuals can consider the least-polluting and most-efficient vehicle that meets their needs (36). Reducing air travel has a substantial impact. Avoiding even one trip can be equivalent to going car-free for a year (37).

Residential energy use for heating, cooling, and powering households accounts for 20% of GHG emissions in the United States (38). Building electrification refers to the shift to using electricity rather than burning fossil fuels for heating and cooking. Reduced emissions can be achieved through retrofits, including electric heat pumps that both heat and cool.

Although these steps are highlighted as actions in our daily personal lives, many can also be applied in hospitals and radiology departments, including supporting sustainable transportation options and increasing access to plant-forward meal options.

Toolkit for Action in Radiology Departments

Given the carbon intensity of health care operations (9), radiologists can have a large positive impact on our departments. Specifically, radiologists can improve health care system sustainability measures, reduce low-value imaging, and reduce the carbon footprint of radiologic services. Table 2 highlights several actions and strategies that radiology departments can implement and their impact on energy and cost savings.

Table 2: Actions to Address Climate Change in Radiology Departments

Action	Rationale	Outcome
Update appropriate use and clinical decision support tools to reduce unnecessary examinations	GHG emissions and energy usage varies by modality. The energy used for a single MRI study is comparable to that used when cooling a three-bedroom house with central air conditioning for 1 day (15).	Appropriate use guidelines for medical imaging could lead to $433 million in cost savings yearly if applied to the Medicare population. Reducing low-value imaging is associated with a lower carbon footprint (60).
Implement clinical AI solutions	Clinical implementation of AI tools could lead to increased diagnostic accuracy, shortened examination times, and decreased downstream testing (43,44). However, this needs to be balanced with the energy used and emissions generated when training AI on large data sets (61).	Potential exists to decrease energy usage and GHG emissions within radiology departments. Currently, there are limited data on potential or real-world reductions in emissions with the use of AI tools (61).
Turn off CT scanners overnight	Approximately two-thirds of energy use in CT occurs in a nonproductive idle state and one-third of energy use for MRI occurs during the system-off state due to cooling requirements (16).	40%–80% of energy can be saved by powering down CT scanners during overnight and weekend nonoperational times (14 000 kWh savings over 1 year for one CT unit) (42).
Switch from single-dose to multidose contrast media delivery	Iodinated contrast media are often purchased in single-dose containers that require unused volumes to be discarded.	A 73% decrease in contrast material waste and 93% reduction in plastic waste can occur by switching from a single-dose to a multidose contrast media delivery system (45).
Improve scheduling efficiency of scanners	The per examination environmental impact of US, CT, and MRI is lower in a 24-hour operations model than an 8 AM to 5 PM workday because the production and maintenance impacts are allocated over a greater number of examinations with less idle time (15).	Decreasing nonproductive idle state time for MRI and CT and increasing the degree of usage per time period (fleet concept) results in a smaller environmental impact per scan (16).
Upgrade rather than replace equipment when feasible	Carbon emissions from the production phase of CT and MRI systems are 2.03 million MJ (564 000 kWh) and 2.73 million MJ (758 000 kWh), respectively (15).	Potential exists for cost and energy savings due to modified production and less waste.
Support remote reporting when feasible	More widespread adoption of remote work would result in less commuter traffic and lower GHG emissions (46).	An 11% reduction in GHG emissions related to transportation can occur with a complete transition to remote work (8.6 megatons of CO_2 equivalent in Canada) (46).

Note.—One megajoule (MJ) is equal to 0.2777 kWh, facilitating comparisons of energy expenditure during production and use phases of equipment. CO_2 equivalent (CO_2e) is a unit of measurement used to standardize the climate effects of various GHGs. The global warming potential (GWP) index expresses the warming effect of a certain amount of a GHG gas over a set period of time (usually 100 years) compared with CO_2. AI = artificial intelligence, GHG = greenhouse gas.

At the health system level, simple energy efficiency and waste reduction measures such as switching to light-emitting diode (LED) lighting, optimizing indoor climate control, and installing occupancy sensors to automate temperature control and lighting are great places to start (16,19).

Low-value imaging provides little to no benefit to patients, has the potential to result in harm, may incur unnecessary costs, and contributes to our environmental footprint (39,40). Unnecessary images also contribute to our carbon footprint due to energy needs for data storage servers and cooling systems (41). Appropriate use and clinical decision support tools can help reduce low-value examinations (15).

With regard to radiologic services, initial efforts can target reducing energy consumption when our scanners and equipment are not in use. Shutting off 29 computers and 25 PACS stations overnight saves 51 tons of CO_2 emissions per year and $7253 (18). Powering down one CT unit during nonoperational times saves 14 000 kWh in 1 year (42). Improved scheduling efficiency can increase scanner usage hours, reduce idle time for MRI and CT, and reduce no-show visits (16,22). Collaboration with building design and facilities teams may be useful to redirect heat generated during scanner operation for waste heat recovery (16). Clinical implementation of artificial intelligence in radiology could lead to higher diagnostic accuracy, shortened examination times, and decreased downstream testing (43,44).

Radiologists can reduce waste by switching to reusable medical supplies, upgrading equipment rather than replacing it, switching to multidose contrast media delivery systems, and purchasing refurbished equipment (15,19,45).

Finally, remote reporting can reduce GHG emissions from radiologists' travel (46). Virtual visits should be supported when feasible to reduce patient travel; for example, for review of imaging results or follow-up after a procedure when in-person evaluation is not needed. Additionally, remote scanning may decrease

Table 3: Actions to Address Climate Change in Health Care Systems and Professional Organizations

Action	Rationale	Outcome
Health care systems		
Turn off electronics and lights when not in use	Electronic devices use energy when they are left on, even when not in active use.	Powering down 29 computers and 25 PACS stations overnight could save 51 tons of CO_2 emissions per year (equivalent to 10 gasoline cars), with an estimated cost savings of $7253 (18).
Install occupancy sensors to improve efficiency of climate control and lighting	Indoor climate control is the largest contributor to GHG emissions in interventional radiology suites (49% of total emissions) (19).	Allowing climate control systems to drift within a wider range of temperatures during times outside scheduled work hours could result in energy and cost savings (62). Potential exists for 0.12 kWh/m^2 annual energy savings in hospitals due to the implementation of energy-efficient bulbs and lighting control systems, with a payback period of less than 2.2 years (63).
Limit single-use disposable medical supplies	Single-use disposable medical supplies were the second largest contributor to GHG emissions in interventional radiology suites in 2021 (41% of total emissions) (19).	Potential exists for significant cost and energy savings, including 515 000 pounds of solid waste and $850 000 in cost savings by switching from single-use gowns to reusable gowns (44,64).
Advocate for sustainable waste management programs	Hospitals generate an average of 1.5 billion kg of solid waste annually (65,66).	Use of the five Rs (reduce, reuse, recycle, rethink, and research) to educate and improve health care waste management saves thousands of dollars; 45% of hospital waste could be diverted by recycling, reprocessing, and reducing waste and restocking or donating unused items (66).
Professional organizations		
Plan virtual or hybrid meetings	Airplane flights are the largest contributor to GHG emissions related to medical conferences (0.540 tonnes CO_2 equivalent per person) (48).	Decreased travel to conferences and meetings would decrease GHG emissions. Options include rotating large conferences with one per year offered virtually on a rotating schedule and moving to hybrid meetings with regional hubs for in-person networking.
Promote research, education, and recommendations to address climate change in radiology	Medical and professional societies can play a leadership role in raising awareness of the impacts of climate change on patients and radiologic services.	Specific recommendations and toolkits for action and education have the potential to inspire change and impact emissions from large numbers of health systems and departments.

Note.—GHG = greenhouse gas, PACS = picture archiving and communication system.

the need for patients to travel for specialized imaging (47). Where remote scanning is not practicable, we can work with vendors to increase access.

Toolkit for Action in Professional Organizations

Climate change will transform health care delivery, and professional organizations can guide radiologists through these changes by raising awareness of the impacts of climate change on patients and imaging services (Table 3). One key role for radiology societies is to suggest strategies for radiology departments to mitigate their carbon footprint and adapt to climate change. Professional organizations can also promote research, quality improvement efforts, and education around the health effects of climate change and health care sustainability. Additionally, medical societies can set a positive example by addressing their own environmental impact. Flights are the largest contributor to GHG emissions related to medical conferences. Thus, virtual or hybrid options can help lessen this impact (48). Regional hubs could be considered to facilitate in-person networking and collaboration. Similar to Leadership in Energy and Environmental Design (LEED) practices with buildings, radiology accreditation organizations can consider certifying sustainable practices.

Toolkit for Action in Relationships with Industry and Vendors

To achieve carbon neutrality, radiologists will need to work with vendors to encourage research and development of sustainable imaging products (Table 4). Vendors have started addressing their impact efforts, as with the European Coordination Committee of the Radiological, Electromechanical and Healthcare IT Industry (COCIR) (49). We can stimulate innovation and user-centered sustainable design through direct collaboration with vendors and by including environmentally sustainable criteria in competitive equipment procurement processes (50). Questions and topics to

Table 4: Actions to Address Climate Change in Our Relationships with Medical Imaging Vendors and Industry Partners

Action	Rationale	Outcome
Implement sustainable procurement policies and strategies	Energy aspects are not currently part of purchasing decisions in most hospitals. Energy usage should be a necessary consideration in purchasing agreements.	The GPP initiative proposes specific energy and other environmental questions for venders. Vendor responses will carry a weight of 15%, with possible energy savings of 50% for MRI and CT and 80% for radiography (50).
Advocate for improved energy consumption in idle and system-off states	Approximately two-thirds of energy use in CT occurs in a nonproductive and idle state and one-third of energy use for MRI occurs during the system-off state due to cooling requirements (16).	The highest improvement potentials relate to the off mode and partly ready-to-scan mode (16,53).
Advocate for remote scanning to reduce travel for patients	Transportation-related GHG emissions for health care can be substantial (47).	Potential GHG and cost savings exist if imaging can be performed locally with remote scanning (67). A shorter commute distance to appointments could decrease no-show rates (22).
Procure life cycle assessments, end-of-life plans, and lifetime energy usages in RFPs	The energy consumption by machine components greatly exceeds other impacts, emphasizing the need for vendor attention to energy-efficient design (15).	There is potential to influence vendors and industry partners to develop greener products throughout life cycles.
Use postconsumer recycled materials within products whenever reusable products are not an option	Postconsumer recycled content is material that is made from items that consumers recycle, including aluminum, cardboard boxes, paper, and plastic bottles.	There are regulatory, technical, infrastructural, and economic barriers to promoting circularity in health care plastics, with potential opportunities to enable greater circular solutions for medical devices and packaging (68).
Optimize recovery and recycling of the waste heat generated by scanners (heat transfer or storage)	Energy demands for HVAC cooling systems are considerable.	Waste heat recovery methods (heat transfer or storage) can be used to recycle heat-related energy rather than spending additional energy to neutralize excess heat (16).
Reduce packaging for medical supplies and devices	Excess packaging increases the carbon emissions and pollution from products used in radiology departments (52).	Packaging alone accounts for 55% of the product weight related to interventional radiology procedures (52). Higher packing density leads to a 33% reduction in packaging area for medical supplies, with less waste and lower transportation energy and costs (69).

Note.—GHG = greenhouse gas, GPP = green public procurement, HVAC = heating, ventilation, and air conditioning, RFP = request for proposal.

consider in request for proposal (RFP) processes are summarized in Tables 5 and S1. The U.S. Environmental Protection Agency is currently developing a new Energy Star product specification for medical imaging equipment (51). These criteria could help radiology departments with sustainable purchasing decisions.

Principles of the circular economy can guide radiologists and our industry partners in sustainable design. The circular economy is a framework for product development focused on the reuse and recycling of materials to reduce raw material extraction and pollution (Fig 4). In contrast, in the traditional linear supply chain, raw materials are extracted to create new single-use disposable products. Considerations in circular design might include the environmental costs of production, the environmental impact of product use, options for product reuse, and strategies to minimize waste and pollution at the end of the product life cycle. Radiologists can start by asking for existing data, such as life cycle analyses, environmental product declarations, or carbon footprints, when making purchasing decisions.

At the beginning of the product life cycle, products can be assessed based on manufacturing choices such as material selection, manufacturing location, manufacturing energy source, transport, and fair labor practices. Material sourcing questions might include the carbon footprint of materials incorporated in a product, whether a product contains chemicals of concern, or if postconsumer recycled materials can be incorporated into product design. Excess packaging increases the carbon emissions and pollution from radiology industry products (52). We can work with vendors to reduce packaging waste or use packaging materials with a lower carbon footprint, such as bioplastics, without negatively impacting patient care.

During the use phase of our equipment, considerations include energy efficiency and the reduction of solid waste. Medical imaging equipment consumes large amounts of power in the idle state and generates heat (16). We can ask for transparency around the energy consumption of our scanners in the active and idle states and work with vendors to improve and automate energy efficiency modes when our

Table 5: Request for Proposal Questions for Medical Imaging Vendors

Category, Questions, and Considerations
Manufacturing
How are the product(s), equipment, or packaging manufactured?
Using technology that reduces energy and/or uses renewable energy sources, including solar, wind, hydropower, geothermal, and biomass
Using technology that reduces water consumption (eg, eliminating wastage, controlled or intelligent watering systems, retrofitting machinery, and reusing wastewater)
Using natural materials or chemicals that meet the 12 green chemistry principles (70)
How are greenhouse gas emissions reduced during the manufacturing process and transport of the proposed product(s) or equipment?
What strategies are used during the manufacturing process to reduce waste?
Including information about any hazardous waste generated
What, if any, chemicals of concern are used in the manufacture of all proposed products or equipment?
Packaging, transport, and distribution
Does the product(s) or equipment arrive in packaging?
That reduces solid waste generation at disposal (eg, bulk or loose products, package take-back program, reusable packaging, and correct sizing)
That is made from postconsumer recycled materials (provide percentage)
That is recyclable in one of the following streams: paper, cardboard, hard plastics (#1, 2, 5), metal, or organics
What are steps being taken to decrease emissions from transport?
Including electric vehicle fleet, local manufacturing strategies, and decreased product weight
Energy use
Does the product or equipment meet U.S. Environmental Protection Agency Energy Star (pending 2023) or European Union Green Public Procurement specifications (51,71,72)?
Specifically for equipment, is there a way to reduce energy consumption during transport to the user?
What are the environmental life cycle assessments and/or product declarations?
Refurbish, reuse, recycle
What strategies are used for remote software updates to keep equipment current?
What plans and opportunities have been identified for recycling and/or reusing components at the product end of life?
What end-of-life disposal and/or recycling procedures are in place for each product?
Corporate environment
What is your corporate climate action plan?
How is your company addressing issues of corporate social and governance responsibility, environmental sustainability, and climate change? (Please provide documentation, as applicable.)
Policies, strategies, initiatives, and other implementations related to your operations or supply chain
Extended producer responsibility
Public reporting of corporate social responsibility, environmental sustainability, greenhouse gas, etc
Third-party environmental certifications, including preferred ISO certifications such as environmental management (ISO 14001), sustainable procurement (ISO 20400), and social responsibility (ISO 26000)

Note.—Green public procurement criteria for electric and electronic equipment used in the health care sector are not up to date as of 2022. ISO = International Organization for Standardization.

scanners are idle (16,53). Decreasing idle state energy will reduce heat production from scanners. We can also work with vendors to optimize the recovery and recycling of waste heat generated by scanners (heat transfer or storage) in the active phase (16). Steps to reduce waste from radiologic services during the use phase include recycling contrast media, reducing the use of helium, and partnering with vendors to design reusable items that meet infection control standards.

At the end of medical equipment life, we can evaluate the circular design of a product based on options for reprocessing and refurbishing, product and material take-back, and part and raw material recycling.

Funding will be critical to support research related to climate change and radiology. While there are already funding opportunities for studying climate change and health from the National Institutes of Health and the Agency for Healthcare Research and Quality, these have not yet focused on radiology. The field of radiology could greatly benefit from research and technical development of more energy-efficient scanners. Given its mission, we propose that the National Institute of Biomedical Imaging and Bioengineering consider requesting such applications under the Bioengineering Partnerships with Industry mechanism.

Conclusion

On the current trajectory of GHG emissions, climate change will become the defining narrative of human health (2). Mitigating emissions offers the opportunity for a future in which

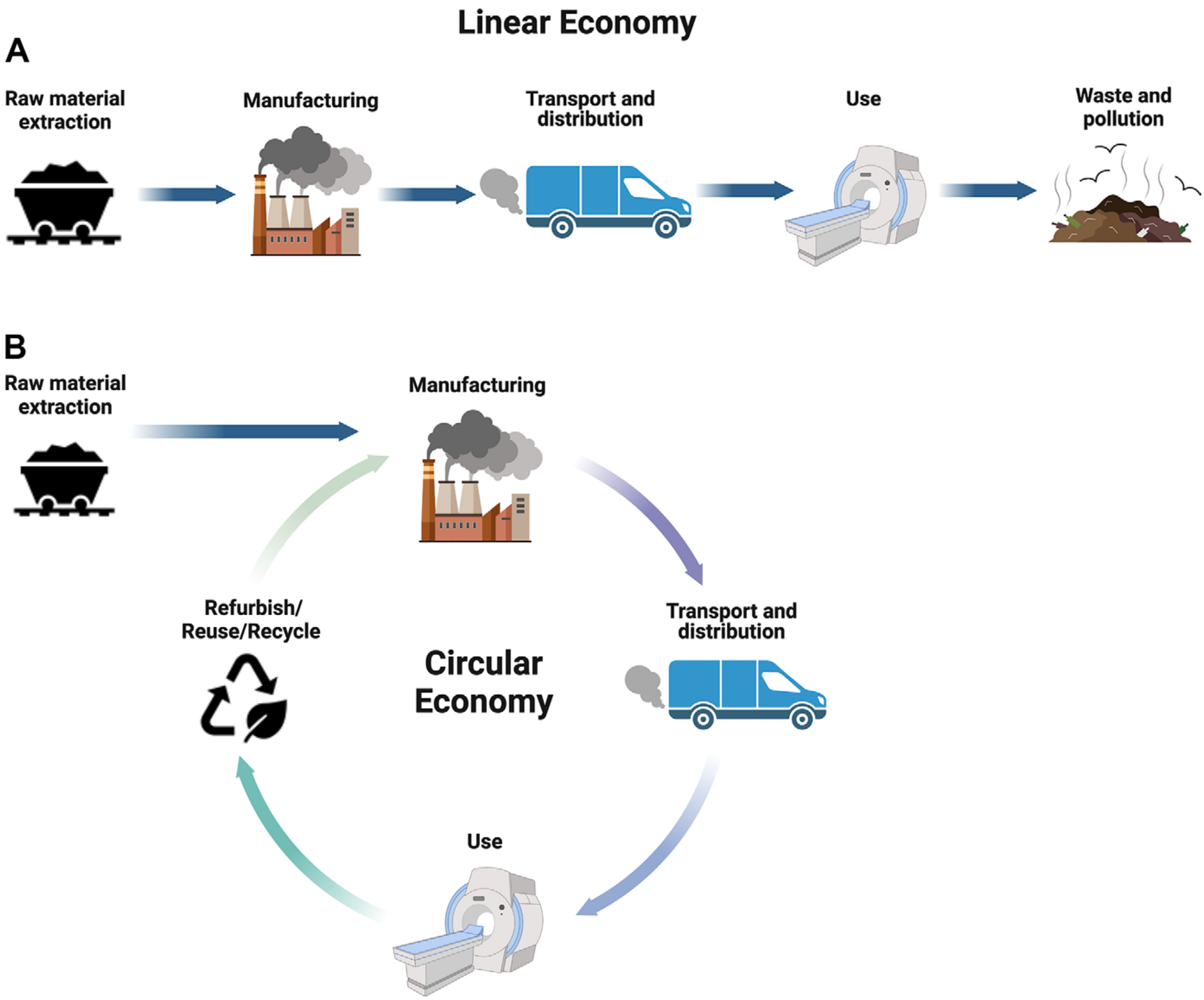

Figure 4: Product life cycle assessment. In a linear economy **(A)**, natural resources are extracted, consumed, and eventually disposed of as waste. This is inefficient compared with a circular economy **(B)**, in which a product is designed to reduce waste and maximize material value over its life span through reuse and recycling. Created with BioRender.com.

local and global populations not only survive but thrive. Radiologists are adept at dealing with rapid technological change. Thus, our role in the health care system confers an opportunity to lead low-carbon sustainable initiatives in our workplaces, our homes, and our communities.

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