

Green Imaging In The Age Of Artificial Intelligence: Building Sustainable Medical Imaging Systems

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ABSTRACT

Medical imaging is essential for modern diagnosis, treatment planning, screening, and monitoring, but imaging services also consume substantial energy and resources. At the same time, artificial intelligence (AI) is rapidly becoming integrated into radiology and medical imaging through automated detection, image reconstruction, workflow optimization, triage, and decision support. AI therefore presents a dual opportunity: it can increase the environmental burden of healthcare through computational energy demand, while also helping imaging departments reduce unnecessary examinations, shorten scan times, improve equipment utilization, and optimize workflows. Recent evidence shows that environmental sustainability of AI in radiology remains an emerging field, with reported concerns including energy consumption, carbon emissions, computational resources, and water use. This article reviews the relationship between sustainability and AI in medical imaging, discusses major sources of environmental impact, explores how AI can support greener imaging practices, and proposes practical strategies for responsible implementation. Sustainable medical imaging should not mean reducing access to appropriate imaging; rather, it should focus on delivering clinically valuable imaging with the lowest reasonable environmental and resource burden.

Keywords: Artificial intelligence; Medical imaging; Radiology; Environmental sustainability; Green radiology; Carbon footprint; Energy efficiency; Machine learning; Sustainable healthcare.

INTRODUCTION

Medical imaging has become an essential component of modern healthcare, supporting diagnosis, treatment planning, screening, and disease monitoring through modalities such as computed tomography (CT), magnetic resonance imaging (MRI), radiography, ultrasound, mammography, nuclear medicine, and interventional imaging. However, the increasing use of imaging technologies is associated with environmental impacts related to energy consumption, equipment operation, carbon emissions, consumables, waste generation, and the life cycle of imaging systems. Recent research has therefore highlighted the importance of considering environmental sustainability as part of modern radiology practice.⁵

A systematic review of environmental sustainability in radiology identified energy consumption, life-cycle assessment, and carbon footprint as important areas of concern. The review also reported that a substantial proportion of the energy consumed by radiological

equipment may occur during non-productive periods, indicating that equipment utilization and operational efficiency represent potential opportunities for reducing environmental impact.²

At the same time, artificial intelligence (AI) is increasingly being incorporated into medical imaging for image reconstruction, detection, segmentation, workflow optimization, scheduling, and clinical decision support. However, AI has a dual relationship with environmental sustainability. The development and deployment of AI models can require substantial computational resources and energy, contributing to greenhouse-gas emissions. Conversely, appropriately implemented AI may improve sustainability by shortening MRI acquisition times, optimizing scanner scheduling, and supporting the reduction of low-value imaging.³

The environmental sustainability of AI in radiology is an emerging area of research. A recent scoping review identified energy consumption, carbon footprint, computational resources, and water consumption as

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major themes in the existing literature. It also highlighted potential strategies such as lightweight AI models, pruning, quantization, efficient optimization, and standardized environmental reporting.¹ These findings indicate that AI systems should be evaluated not only for diagnostic performance but also for their environmental and computational requirements.

The broader implementation of AI in healthcare also requires attention to safety, ethics, equity, governance, and sustainability. The World Health Organization emphasizes that AI for health should be developed and implemented in a manner that is safe, ethical, equitable, and appropriately governed.⁴ Therefore, the adoption of AI in medical imaging should consider not only technological performance but also its wider effects on healthcare systems, patients, resources, and the environment.

Together, these considerations support the concept of green imaging, in which medical imaging services seek to provide clinically valuable examinations while minimizing avoidable environmental and resource burdens. Recent evidence indicates that radiology's environmental footprint extends across energy use, waste, contrast media, equipment, and other aspects of imaging practice, while significant gaps remain in standardized environmental measurement and life-cycle assessment.⁵ Integrating sustainability principles into AI development, imaging workflows, equipment management, and clinical decision-making may therefore contribute to more environmentally responsible and efficient medical imaging systems.

2. Environmental Footprint Of Medical Imaging

The environmental impact of medical imaging is multidimensional. First, imaging equipment consumes electricity during scanning, standby periods, image reconstruction, data transfer, and cooling. MRI systems may have particularly high energy requirements because of their continuous operation and supporting infrastructure. CT scanners also require significant electricity, while radiography and ultrasound generally have lower energy demands.

Second, the manufacture and disposal of imaging equipment contribute to resource consumption and greenhouse-gas emissions. Components such as electronics, metals, magnets, detectors, and cooling

systems have environmental impacts throughout their life cycle. Extending equipment life through appropriate maintenance, refurbishment, and responsible procurement can therefore complement energy-saving measures.

Third, imaging produces clinical waste and uses consumables. Contrast media, syringes, packaging, protective materials, and nuclear medicine-related materials require appropriate management. Water contamination from pharmaceuticals and contrast agents is another emerging sustainability concern.

Finally, digital imaging creates a rapidly expanding data footprint. PACS archives, cloud storage, AI datasets, and repeated image processing require servers and networking infrastructure. As imaging volumes and AI applications increase, the environmental impact of computation and storage becomes increasingly relevant.

3. Artificial Intelligence: Environmental Challenge And Opportunity

AI has a dual relationship with sustainability in medical imaging. On one side, AI models may require substantial computational resources, especially during training. Large datasets, repeated model development, high-performance GPUs, long training cycles, and continuous inference can increase electricity demand. The environmental burden depends on factors such as model size, number of training experiments, hardware efficiency, data-center efficiency, electricity source, and frequency of use.

On the other side, AI can reduce environmental impact when it improves the efficiency of imaging services. AI-assisted image reconstruction may allow faster MRI acquisition or support reconstruction from fewer measurements while maintaining diagnostic quality. AI can also improve scanner scheduling and reduce idle time, support protocol selection, automate quality checks, and help identify examinations that may not provide sufficient clinical value.

AI-based decision support may also contribute to reducing low-value imaging by helping clinicians select appropriate examinations and avoid unnecessary repeat studies. When clinically validated, such applications can reduce patient travel, scanner

utilization, contrast use, and associated resource consumption.

Thus, AI should not automatically be considered “green.” Its sustainability depends on whether the environmental cost of developing and operating the system is justified by the clinical and operational benefits it provides.

4. Sustainable AI Strategies In Medical Imaging

Several strategies can reduce the environmental impact of AI:

4.1 Lightweight Models: Smaller architectures can reduce memory requirements, processing time, and energy consumption while maintaining clinically acceptable performance for focused tasks.

4.2 Pruning And Quantization: Removing unnecessary model parameters and reducing numerical precision can decrease computational requirements. These approaches should be validated carefully to ensure that diagnostic performance is not compromised.

4.3 Efficient Training: Early stopping, efficient optimizers, transfer learning, and careful experiment design can reduce unnecessary training cycles. Reusing validated models rather than repeatedly training large models from scratch may also lower resource use.

4.4 Energy-aware Infrastructure: AI workloads can be deployed on efficient hardware and, where appropriate, data centers powered by lower-carbon electricity. Energy and carbon metrics should be monitored rather than assumed.

4.5 Standardized Environmental Reporting: AI studies should report relevant information such as training duration, hardware type, energy consumption where measurable, model size, computational workload, and carbon estimates. Standardized reporting would allow meaningful comparison between systems.

4.6 Life-cycle Assessment: Sustainability should be considered from model development through deployment, maintenance, updating, storage, and end-of-life. Current research still has important gaps in

assessing the complete life cycle of AI used in radiology.

5. AI Applications That Can Support Greener Imaging

AI can contribute to sustainable medical imaging through several clinical and operational pathways:

- **Faster MRI:** AI-assisted reconstruction can help reduce acquisition time in selected applications, potentially decreasing scanner operating time and improving patient throughput.

- **Protocol optimization:** AI can assist in selecting efficient imaging protocols and parameters while maintaining diagnostic quality.

- **Workflow optimization:** Predictive systems can improve scheduling, reduce gaps between examinations, and increase utilization of existing equipment.

- **Automated quality control:** AI can detect motion, positioning, artifacts, or technically inadequate examinations, potentially reducing unnecessary repeat scans.

- **Decision support:** Appropriate-use tools can help reduce examinations that are unlikely to add clinical value.

- **Triage and prioritization:** AI can identify urgent findings and streamline workflow, potentially reducing delays and unnecessary downstream resource use.

- **Remote and digital workflows:** Efficient image analysis and reporting can support distributed care and may reduce some travel-related emissions, although the environmental impact of additional computing must also be considered.

The key principle is that sustainability benefits should be demonstrated in real clinical workflows rather than assumed from the presence of AI.

6. Barriers And Ethical Considerations

Sustainable AI in medical imaging faces several challenges. The first is the lack of standardized environmental metrics. Different studies measure energy, carbon emissions, water consumption, or

computational workload in different ways, making comparisons difficult. The recent literature indicates that research in this area remains limited.

Second, sustainability must not compromise patient safety. A smaller or faster AI model is not preferable if it reduces diagnostic accuracy, increases bias, or performs poorly in underrepresented populations. Clinical validation, quality assurance, cybersecurity, privacy, and regulatory compliance remain essential.

Third, the benefits of AI may not be equally distributed. High-resource institutions may have access to efficient computing infrastructure and advanced AI systems, whereas smaller hospitals may face financial and technical barriers. Sustainable innovation should therefore also consider affordability, accessibility, interoperability, and health equity.

Finally, healthcare organizations should avoid “green AI” claims without measurable evidence. Environmental performance should be evaluated using transparent indicators and, ideally, life-cycle approaches.

7. Practical Framework For Sustainable Medical Imaging

A practical sustainability framework can be implemented at the departmental level:

1. Measure: Establish Baseline Electricity Use, Equipment Utilization, Imaging Volume, Repeat Examinations, Data Storage, Consumables, And Major Sources Of Waste.

2. Reduce: Minimize Idle Equipment Time, Unnecessary Repeat Scans, Avoidable Data Duplication, And Inefficient Workflows.

3. Optimize: Use AI And Automation Only Where They Provide Measurable Clinical Or Operational Value.

4. Monitor: Track Model Performance Together With Energy, Carbon, Computational, And Resource Indicators.

5. Validate: Confirm That Sustainability Interventions Do Not Compromise Diagnostic Quality, Patient Safety, Or Equity.

6. Improve: Periodically Reassess AI Models, Equipment, Protocols, And Workflows As Technologies And Energy Sources Change.

This framework shifts sustainability from a one-time project to a continuous quality-improvement process.

8. Future Directions

Future research should move beyond demonstrating that AI can be accurate and should evaluate whether AI systems are efficient, scalable, and environmentally responsible. Prospective studies could compare the environmental impact of conventional and AI-assisted imaging workflows. Standardized reporting of energy consumption, carbon emissions, computing requirements, and water use would improve transparency.

The development of eco-labels or sustainability scores for medical AI systems could help hospitals include environmental performance in procurement decisions. Research should also explore life-cycle assessment from hardware manufacture to model retirement. Collaboration among radiologists, radiographers, medical physicists, AI researchers, hospital engineers, sustainability teams, and policymakers will be essential.

Importantly, sustainable imaging should focus on value-based care. The goal is not simply to perform fewer scans, but to perform the right examination, at the right time, using an efficient protocol, and to obtain maximum clinical value from every examination.

CONCLUSION

Artificial intelligence is neither inherently sustainable nor inherently harmful to the environment. In medical imaging, it represents a double-edged technology. Computationally intensive AI development can increase energy use and carbon emissions, but appropriately designed AI can also improve imaging efficiency, shorten scan times, optimize workflows, reduce repeat examinations, and support appropriate use of imaging.

The future of radiology should therefore combine digital innovation with environmental responsibility. Sustainable medical imaging will require measurement, efficient technology, life-cycle

thinking, transparent reporting, and strong clinical validation. By integrating sustainability into AI development and radiology operations, healthcare systems can pursue a model of imaging that is clinically effective, economically responsible, and environmentally conscious.

DECLARATIONS

Authors' Contributions

S.J. (Sakshi M. Jadhav): Conceptualization, literature search, manuscript drafting, and editing.

H.G. (Harihar V. Gunge): Conceptualization, critical revision, supervision, and submission coordination.

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