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## Green & Sustainable Radiology: Advancing One Health Through Energy Efficiency & Environmental Responsibility

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### HIGHLIGHTS

- MRI highest energy use
- HVAC major power consumer
- Imaging enables early detection
- AFP difficult during pregnancy
- Teamwork improves maternal outcomes

### Key Words:

Green radiology  
Energy efficiency  
MRI  
One Health  
Sustainability

### ABSTRACT

**Introduction:** Radiology is essential to modern healthcare, but advanced imaging modalities such as magnetic resonance imaging and computed tomography are highly energy-intensive. Continuous equipment operation, cooling systems, and digital infrastructure significantly increase electricity use and carbon emissions. With growing climate concerns and healthcare energy demands, integrating sustainability into radiology practice is crucial within the One Health framework. **Aim & Objectives:** This study aimed to evaluate the electricity consumption profile of a hospital radiology department and assess the impact of structured energy-efficiency interventions. The objectives were to identify major energy-consuming equipment, quantify baseline electricity use, and determine potential reductions achievable through uniform efficiency measures. **Materials & Methods:** This observational, evidence-based assessment evaluated the monthly electricity consumption of radiology and HVAC equipment before and after a standardized 30 percent energy-efficiency intervention. Equipment-wise power use was recorded, categorized, and compared to determine absolute and relative reductions in energy demand. **Results:** Baseline analysis demonstrated a highly skewed consumption pattern, with the MRI system accounting for more than half of total monthly electricity use, followed by air conditioning and CT scanners. After intervention, total monthly consumption decreased from 24,419 kWh to 17,094 kWh, achieving a net reduction of 7,325 kWh. The largest absolute savings were observed in MRI, HVAC systems, and CT scanners, while low-power devices showed minimal impact. **Conclusion:** Targeted energy optimization in high-load imaging and climate control systems can produce substantial electricity savings without compromising diagnostic services. Adoption of sustainable radiology practices represents a practical pathway to reduce healthcare carbon footprint while supporting environmental and public health goals.



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## INTRODUCTION

Radiology plays an indispensable role in contemporary healthcare by enabling accurate diagnosis, guiding clinical decision-making, and monitoring treatment responses across a wide spectrum of medical conditions [1]. However, the advanced imaging technologies that drive these clinical benefits particularly modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) also carry substantial environmental costs [2]. These imaging systems, along with associated infrastructure and data-processing technologies, consume significant amounts of electrical energy during both active scanning and idle time, contributing materially to the overall energy footprint of healthcare facilities [3]. Evidence indicates that the energy required to operate multiple CT and MRI scanners can account for a noteworthy portion of a hospital's total electricity usage, highlighting the substantial environmental toll of routine imaging operations if left unchecked [4].

Beyond energy use, radiology departments contribute to environmental pressures through the lifecycle impacts of consumables, waste streams, and associated activities [5]. Single-use items in interventional radiology and routine procedures generate consi-

derable solid waste, while contrast media and related chemical agents raise concerns regarding water pollution and ecological disruption when discharged improperly [6]. The cumulative impact of these materials, combined with greenhouse gas emissions from equipment operation, staff and patient transportation, and facility energy demands, underscores the multifaceted nature of radiology's environmental footprint [7]. Recognizing and quantifying these impacts is a vital first step toward embedding sustainability into routine clinical practice [8].

Green and sustainable radiology represents a proactive integration of environmental stewardship into imaging practice, balancing high-quality patient care with energy conservation, emission reduction, and waste minimization [9]. Grounded in the One Health framework, it recognizes that human health is closely interconnected with ecosystem integrity, and that environmentally responsible radiology can deliver clinical as well as broader public health benefits [10].

Energy efficiency represents a cornerstone of sustainable radiology efforts. Studies have documented the potential for significant reductions in energy consumption by optimizing equipment use and workflow processes [11]. For example, reducing the amount of time that imaging systems remain powered



Figure 1: Green & Sustainable Radiology framework showing One Health approach, key stakeholders, and strategies for energy efficiency and environmental impact reduction. *Adapted from BioRender.*

powered but idle, implementing power-save modes, and improving patient scheduling can collectively lower non-productive energy usage without compromising care quality. These measures not only reduce the operational carbon footprint of radiology services but also offer potential cost savings for healthcare institutions, thereby aligning environmental and economic incentives [4].

Advancements in equipment design and technology also contribute to environmental sustainability. Newer imaging systems are often engineered with improved energy-efficiency profiles, using less electrical power per scan while maintaining diagnostic performance [12]. Furthermore, digital transformation including the use of cloud-based image storage, advanced data compression, and optimized picture archiving and communication systems (PACS)- reduces reliance on physical storage media and supports more streamlined, lower-energy workflows [13]. Although digital systems themselves consume energy, thoughtful implementation and optimization of digital radiology workflows can lessen overall environmental impact and support more sustainable clinical operations [10].

Waste management and materials stewardship form another essential dimension of sustainable radiology [14]. Recycling initiatives for imaging materials, such as old film or surplus supplies, and proper segregation of clinical waste from general waste, reduce landfill burdens and can reclaim valuable components like silver from radiographic films [15]. In addition, careful handling and disposal of contrast media and other chemical agents potentially through recovery systems or advanced waste treatment, can mitigate downstream environmental effects. Educating radiology staff on sustainable waste practices and integrating environmental considerations into procurement decisions further embeds sustainability into departmental culture and decision-making [4].

The transition toward sustainable radiology requires organizational action. Leaders and professional societies promote sustainability frameworks, policies, and standardized environmental metrics. Collaboration with equipment manufacturers and healthcare administrators enables greener technologies and capital investments. Embedding sustainability indicators into quality reporting and performance evaluation reinforces eco-responsible practices as core institutional priorities globally [14].

Crucially, sustainable radiology does not detract from clinical excellence. On the contrary, optimizing resource use, enhancing

workflow efficiency, and reducing unnecessary imaging can improve patient experience, reduce wait times, and foster more judicious use of healthcare resources [16]. For instance, adopting accelerated imaging protocols or favoring less energy-intensive modalities when clinically appropriate can maintain high standards of care while lowering environmental impact. These strategies illustrate how environmental responsibility and clinical effectiveness can co-exist and support one another [17].

Green and Sustainable Radiology is a forward-looking paradigm that addresses environmental impacts of imaging while supporting equitable, high-quality care [18]. Through energy efficiency, waste reduction, digital innovation, and organizational commitment, radiology advances planetary health. Aligned with the One Health approach, it recognizes environmental stewardship as essential to protecting human health for present and future generations [10]. Conceptual framework of Green & Sustainable Radiology (**Figure 1**) showing the One Health approach, integrating stakeholders with strategies like energy efficiency, waste reduction, sustainable procurement, and monitoring to reduce environmental impact and improve healthcare outcomes.

This study aims to highlight the importance of green and sustainable practices in radiology in alignment with One Health principles. The objectives are to assess the environmental impact of radiology departments, outline energy optimization, digital transformation, and waste management strategies, and emphasize policy support to reduce carbon footprint while improving economic and healthcare sustainability.

## MATERIALS & METHODS

This presentation was developed as a narrative, evidence-based review focusing on sustainability practices applicable to radiology departments. Data were derived from published peer-reviewed literature, national policy documents, and operational benchmarks related to energy consumption, carbon emissions, digital imaging, and waste generation in radiology services. Information on energy usage, cost burden, and carbon footprint was synthesized from existing studies, while government initiatives such as ABDM and PM Surya Ghar Yojana were reviewed for policy alignment. Practical strategies, including energy audits, digital transformation, green building design, and waste management, were systematically analyzed to formulate recommendations consistent with One Health principles. **Figure 2** illustrates staff orientation aimed at promoting energy conservation in healthcare settings through awareness, training, and adoption of sustainable practices.



**Figure 2: Staff orientation for promoting energy conservation**

## RESULTS

**Table 1** and **Figure 3** demonstrate a highly skewed electricity consumption profile, with the Siemens 1.5T MRI system accounting for the largest share due to continuous operation and chiller load. Air conditioners and CT scanners are the next major contributors, reflecting the energy-intensive requirements of thermal control and high-power imaging. In contrast, conventional radiography, ultrasound, lighting, and IT equipment contribute relatively modest and distributed loads. Overall, the data indicate that advanced cross-sectional imaging and HVAC systems dominate baseline energy demand, making them the primary targets for any efficiency intervention. **Table 2** and **Figure 4** demonstrate that a uniform 30 percent energy-efficiency intervention produces a substantial absolute reduction in electricity consumption, with the greatest savings occurring in high-load imaging equipment such as MRI, CT scanners, and centralized air-conditioning systems. These devices dominate baseline energy demand due to continuous operation, cooling requirements, and high power ratings, so proportional reductions translate into large kWh savings. In contrast, low-power devices such as printers and view boxes show minimal absolute change despite the same percentage reduction. Overall, the pattern indicates that targeted efficiency measures in energy-intensive diagnostic infrastructure yield the most meaningful impact on total hospital electricity consumption. **Table 3** shows that the energy efficiency intervention reduced total monthly electricity consumption from 24419 kWh

kWh to 17,094 kWh, resulting in an absolute saving of 7,325 kWh. This reduction corresponds precisely to a 30 percent decrease, indicating effective and consistent implementation across electrical loads. The magnitude of savings reflects cumulative reductions from multiple high consumption systems rather than isolated low-power devices.

**Table 4** and **Figure 5** indicate that the largest monthly electricity savings were achieved from high-energy diagnostic equipment, particularly MRI, air-conditioning systems, and CT scanners, which together contribute the majority of total reductions. These systems have high baseline power demands, so efficiency interventions yield substantial absolute energy savings. In contrast, lower-power devices such as computers, view boxes, and printers contribute relatively small reductions despite proportional improvements. Overall, the findings emphasize that prioritizing energy optimization in high-load medical equipment is critical for achieving meaningful reductions in total electricity consumption. **Table 5** and **Figure 6** show that MRI systems are the dominant contributors to baseline electricity consumption, accounting for over half of total monthly energy use, primarily due to continuous operation and chiller dependency. Air-conditioning and CT scanners together contribute nearly one-third of overall consumption, reflecting their high-power intensity and extended operational hours. In contrast, the combined contribution of all other equipment remains comparatively modest despite their greater numbers. This distribution highlights that energy management strategies should prioritize MRI and climate control systems to achieve the greatest reductions in total electricity demand.

**Table 1: Electricity Consumption of All Instruments (Before Intervention)**

S. No.	Equipment	Monthly Electricity Consumption (kWh)
1.	Siemens MRI 1.5T (including chiller)	12,960
2.	Air Conditioners (12 units)	4,608
3.	Philips CT Scan (128 -slice)	2,880
4.	AMX X-ray CR (2 units)	720
5.	Allengers X-ray DR	480
6.	USG Machines (GE/Esote/Aeroscan/Alpion)	480
7.	LED Lights (80 units)	480
8.	Fans (15 units)	405
9.	Computers (7 units)	252
10.	View Boxes (3 units)	90
11.	Allengers Portable X-ray (2 units)	72
12.	Printers (4 units)	12

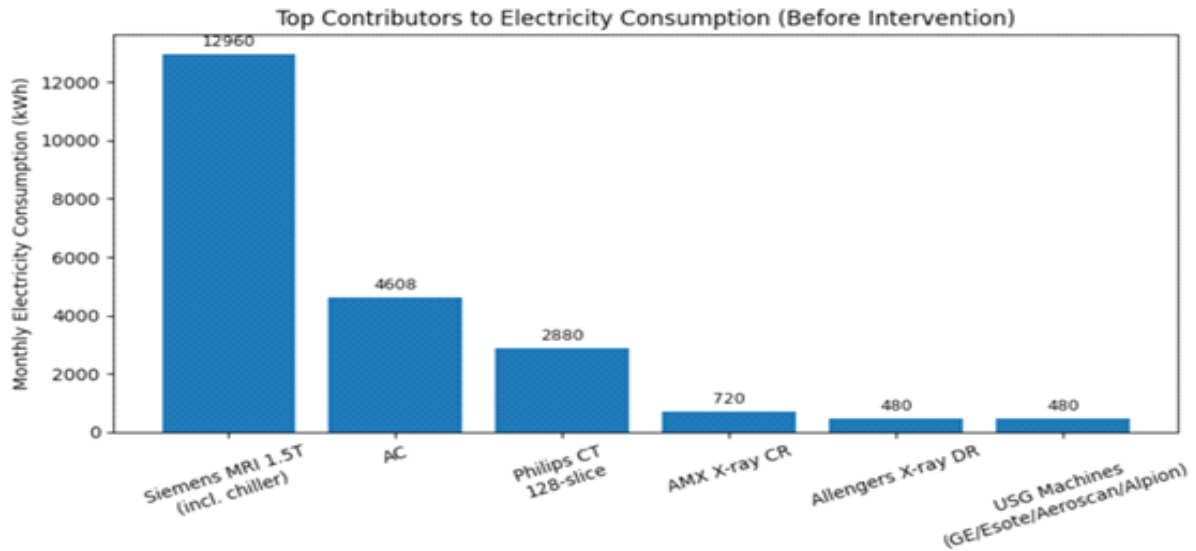


Figure 3: Major Imaging and HVAC Contributors to Monthly Electricity Consumption Prior to Energy Intervention

Table 2: Electricity Consumption After Intervention (30% Reduction)

S. No.	Equipment	Monthly kWh (Before)	Monthly kWh (After 30% Reduction)
1.	Siemens MRI 1.5T (including chiller)	12,960	9,072
2.	Air Conditioners (12 units)	4,608	3,226
3.	Philips CT Scan (128 -slice)	2,880	2,016
4.	AMX X-ray CR (2 units)	720	504
5.	Allengers X-ray DR	480	336
6.	USG Machines (GE/Esote/Aeroscan/Alpion)	480	336
7.	LED Lights (80 units)	480	336
8.	Fans (15 units)	405	284
9.	Computers (7 units)	252	176
10.	View Boxes (3 units)	90	63
11.	Allengers Portable X-ray (2 units)	72	50
12.	Printers (4 units)	12	8

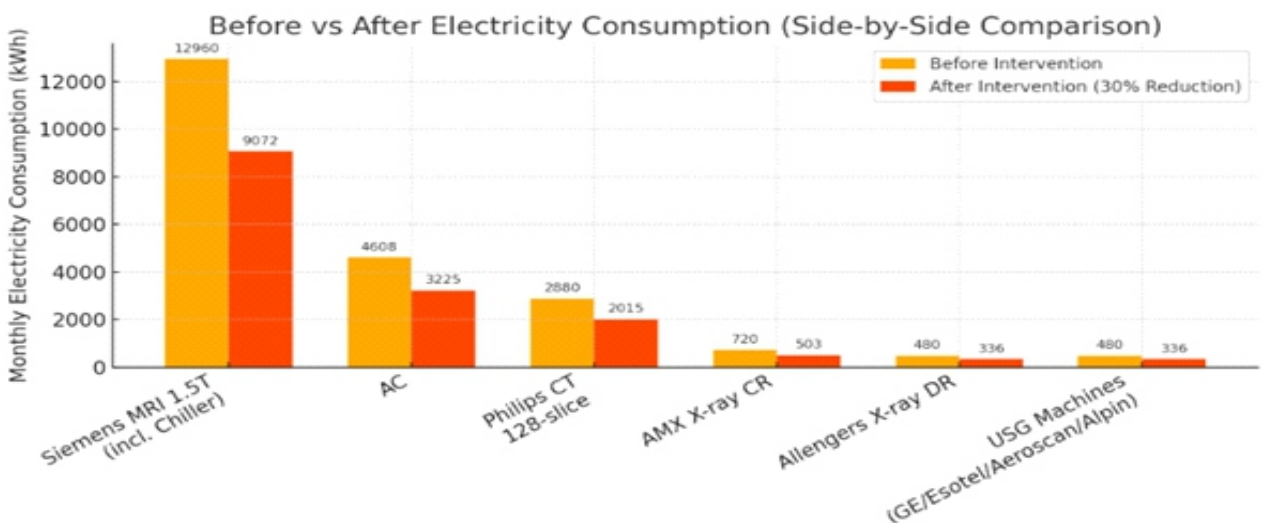


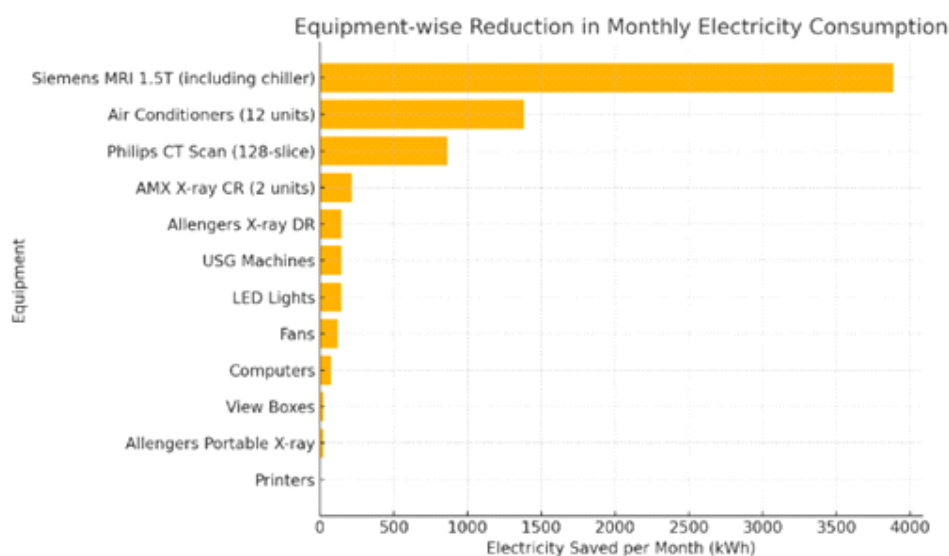
Figure 4: Close-up view of the tumour surface showing prominent vascularity and cystic areas, with aspiration of reactive peritoneal fluid.

**Table 3: Overall Monthly Electricity Consumption Before and After Intervention**

Parameter	Monthly Electricity Consumption (kWh)
Total consumption before intervention	24,419
Total consumption after intervention	17,094
Net reduction in electricity consumption	7,325
Percentage reduction achieved	30%

**Table 4: Equipment-wise Reduction in Monthly Electricity Consumption**

Equipment	Electricity Saved per Month (kWh)
Siemens MRI 1.5T (including chiller)	3,888
Air Conditioners (12 units)	1,382
Philips CT Scan (128 -slice)	864
AMX X-ray CR (2 units)	216
Allengers X-ray DR	144
USG Machines	144
LED Lights	144
Fans	121
Computers	76
View Boxes	27
Allengers Portable X-ray	22
Printers	4

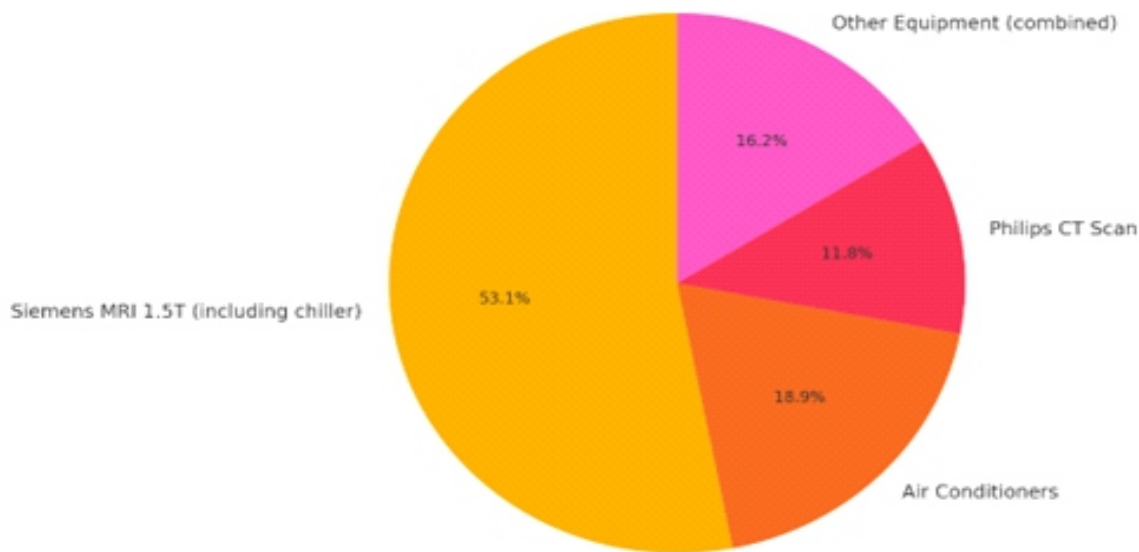


**Figure 5: Equipment-wise Reduction in Monthly Electricity Consumption**

**Table 5: Percentage Contribution of Equipment to Total Electricity Consumption (Before Intervention)**

Equipment Category	Monthly Consumption (kWh)	Contribution (%)
Siemens MRI 1.5T (including chiller)	12,960	53.1
Air Conditioners	4,608	18.9
Philips CT Scan	2,880	11.8
Other Equipment (combined)	3,971	16.2
<b>Total</b>	<b>24,419</b>	<b>100</b>

## Percentage Contribution of Equipment to Total Electricity Consumption (Before Intervention)



**Figure 6: Percentage Contribution of Major Equipment to Total Electricity Consumption (Before Energy-Saving Measures)**

#### DISCUSSION

The observed highly skewed electricity consumption profile, dominated by the Siemens 1.5 T MRI system, is consistent with published evidence demonstrating that MRI energy demand is driven largely by continuous baseline operation and cooling infrastructure rather than scan time alone. **Woolen et al. (2023)** showed that MRI systems consume substantial non-productive energy due to standby power and chiller loads, making them the principal contributors to radiology energy footprints. Similarly, **Heye et al. (2020)** reported that MRI and CT scanners account for the highest annual electricity consumption among imaging modalities, whereas radiography and ultrasound contribute comparatively minor loads. These findings validate prioritizing MRI, HVAC, and CT for targeted efficiency interventions [19,20].

The uniform 30 percent energy efficiency intervention resulted in the greatest absolute electricity savings from MRI systems, CT scanners, and centralized air conditioning, reflecting their dominance in baseline hospital energy demand. Prior studies show that high-load imaging equipment operates continuously and requires substantial cooling, so proportional efficiency gains translate into large kWh reductions rather than marginal savings. **Woolen et al. (2023)** demonstrated that reductions in MRI standby power and cooling loads yield disproportionate absolute energy benefits compared with low-power devices. Similarly, a recent systematic review by **Chen Xu et al. (2024)** confirmed that targeting HVAC and major diagnostic infrastructure produces the most meaningful impact on total hospital electricity consumption [19,21].

The observed reduction in monthly electricity consumption from 24,419 kWh to 17,094 kWh, representing an exact 30 percent decrease, indicates effective and uniform implementation of the energy efficiency intervention across major electrical loads. Similar magnitudes of savings have been reported in hospital settings when system-wide measures target high consumption infrastructure rather than isolated devices. **Cacabelos Reyes et al. (2020)** demonstrated that optimized operational control of hospital HVAC systems can produce substantial aggregate energy reductions through coordinated load management. Likewise, **Chen et al. (2018)** reported that integrated energy saving design and operation of hospital air conditioning systems achieved nearly one-third reduction in energy use [22,23].

The largest monthly electricity savings were derived from MRI systems, centralized air conditioning, and CT scanners, reflecting their high baseline power demand and continuous operational requirements. Prior evidence indicates that these high load diagnostic systems dominate radiology and hospital energy profiles, so efficiency interventions applied to them yield substantial absolute kWh reductions. **Woolen et al. (2023)** demonstrated that MRI energy consumption is driven largely by standby and cooling loads, making it highly responsive to optimization measures. Similarly, **Heye et al. (2020)** reported that CT and MRI account for the majority of imaging related electricity use, whereas low power devices contribute minimally to overall savings despite proportional efficiency improvements [19,20].

MRI systems accounted for the majority of baseline electricity consumption, exceeding half of total monthly use, largely due to

continuous operation and dependence on dedicated chiller systems. Similar patterns have been reported in prior studies, which show that MRI energy demand is driven predominantly by non-scanning standby and cooling loads. **Woolen et al. (2023)** demonstrated that MRI infrastructure contributes disproportionately to radiology energy footprints, making it the primary target for effective energy management interventions. In addition, **Heye et al. (2020)** reported that CT scanners and climate control systems together represent a substantial share of hospital electricity consumption, whereas the combined contribution of lower-power equipment remains modest despite higher numbers [19,20].

## CONCLUSION

This study demonstrates that radiology departments are significant contributors to hospital electricity consumption, largely driven by high-energy imaging equipment and HVAC systems. The implementation of uniform energy-efficiency interventions achieved a substantial 30 percent reduction in monthly electricity use, with the greatest absolute savings observed in MRI, CT, and air-conditioning systems. These findings highlight that targeted optimization of high-load diagnostic infrastructure can deliver meaningful environmental and economic benefits without compromising clinical performance. Integrating such measures within a One Health framework supports sustainable radiology practice, aligns environmental stewardship with patient care, and represents a practical pathway toward reducing the healthcare sector's overall carbon footprint.

## LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, and a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multicentre designs with larger populations to enhance validity, assess long-term outcomes, and investigate advanced diagnostic and management approaches. Such efforts will improve overall patient care and help minimize complications.

## CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical healthcare applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient care, diagnosis, and treatment outcomes. By highlighting real-world relevance, the study contributes to evidence-based medical practice and supports informed clinical decision-making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

## ABBREVIATIONS

**SR:** Sustainable Radiology

**CF:** Carbon Footprint

**SR-CF:** Sustainable Radiology reduces Carbon Footprint

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## AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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Authors declared that there is no conflict of interest.

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All necessary consent & approval was obtained by authors.

## CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

## DATA AVAILABILITY

All data generated and analyzed are included within this research article. The data sets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

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The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.


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