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Green Hospitals and Green Audits: Building Environmentally Sustainable, Climate-Resilient Health-Care Facilities

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Abstract: Background: Health-care facilities protect health but also consume substantial energy, water, food, pharmaceuticals and materials while generating greenhouse gases, wastewater, hazardous waste and air pollution. Hospitals are simultaneously contributors to environmental degradation and critical infrastructure vulnerable to heat, floods, storms, water scarcity and energy disruption. The concept of a green hospital therefore extends beyond energy-efficient buildings to encompass environmentally sustainable, climate-resilient and clinically safe care. **Objective:** This narrative review examines the principles, components and evidence base of green hospitals and green audits, evaluates recent international and Indian developments, and proposes priorities for implementation, monitoring and research. **Key findings:** Health care accounts for approximately 4%–5% of global greenhouse-gas emissions, with supply chains responsible for the largest share. High-impact opportunities include prevention of unnecessary care, energy efficiency, renewable electricity, low-carbon procurement, rational pharmaceutical and anaesthetic use, waste segregation, water stewardship, sustainable food systems and climate-resilient infrastructure. A green audit establishes a baseline and repeatedly measures environmental performance across governance, energy, emissions, water, waste, procurement, transport, food, chemicals, biodiversity and disaster preparedness. However, audits frequently overemphasize visible measures such as tree planting or solar panels while neglecting indirect supply-chain emissions, clinical pathways and patient outcomes. Evidence is dominated by carbon accounting, life-cycle assessments and institutional case studies; standardized outcome measures and data from low- and middle-income countries remain limited. **Conclusion:** Green hospitals should deliver high-quality care with the lowest feasible environmental harm while remaining safe and functional during climate-related disruptions. India has developed national guidance and accreditation-linked initiatives, but implementation requires trained teams, reliable data, realistic financing, transparent targets and integration with quality assurance. Green auditing should become a recurring management cycle rather than a one-time certification exercise.

Keywords: Green hospital; green audit; sustainable health care; climate resilience; carbon footprint; India

INTRODUCTION

Hospitals embody a fundamental environmental paradox. Their purpose is to prevent illness and restore health, yet their operations depend on energy-intensive buildings, complex supply chains, transportation, pharmaceuticals, plastics, food, water and waste-treatment systems. These activities contribute to air pollution, climate change, resource depletion and ecological damage, which subsequently increase disease and health-care demand.

The global health sector is estimated to contribute approximately 4.4%–5.2% of net greenhouse-gas emissions.[1,2] If the sector were a country, its emissions would place it among the world's largest

national emitters. The burden is highly unequal: high-income health systems account for a disproportionate share, while low-income countries generally have small health-care footprints but greater unmet health needs and higher vulnerability to climate hazards.

Hospital sustainability cannot therefore be reduced to universal carbon-cutting targets applied identically across settings. High-consuming systems must rapidly eliminate wasteful and carbon-intensive care. Lower-resource systems may need to expand energy use, infrastructure and service coverage to achieve universal health coverage. The appropriate objective is not indiscriminate resource reduction, but delivery of equitable, effective care within environmental limits.

A green hospital may be defined as a health-care facility that improves or restores health while minimizing adverse environmental effects and strengthening resilience to climate-related hazards.[3] The term includes both mitigation—reducing emissions and pollution—and adaptation—ensuring that services remain functional during extreme heat, floods, storms, droughts, outbreaks and supply interruptions.

A green audit is the systematic assessment of a facility's environmental impacts, resource use, legal compliance, climate risks and improvement opportunities. Unlike a one-time environmental inspection, a meaningful audit is cyclical: baseline assessment is followed by prioritization, intervention, measurement, reporting and corrective action.

From Green Buildings to Sustainable Clinical Care

Early green-hospital initiatives focused primarily on building design: natural lighting, insulation, energy-efficient equipment, water conservation and green spaces. These remain important, but buildings represent only one component of health-care impact.

Health-care emissions are commonly grouped into three scopes. Scope 1 includes direct emissions from facility-owned sources, such as boilers, generators, hospital vehicles and anaesthetic gases. Scope 2 includes indirect emissions from purchased electricity, steam, heating or cooling. Scope 3 includes the wider value chain—pharmaceuticals, medical devices, food, construction, staff and patient travel, waste treatment and other purchased goods and services.

Supply-chain emissions usually constitute the largest share of the sector's carbon footprint.[1] A hospital can therefore install solar panels and still retain a large environmental footprint if procurement remains resource-intensive, unnecessary investigations continue, medicines are wasted and disposable products are used without clinical justification.

The most sustainable clinical activity is often prevention of disease or avoidance of low-value care. Preventing hospital admission, controlling hypertension in primary care, reducing hospital-acquired infection and avoiding unnecessary imaging can improve health while reducing material and energy use. Environmental sustainability should consequently be incorporated into clinical quality and patient safety, not treated as an unrelated engineering programme.

Core Domains of a Green Hospital

Governance and institutional accountability

Sustainability requires formal governance. Hospitals should establish a multidisciplinary green or climate-resilience committee involving administration, clinicians, nursing, engineering, infection control, procurement, pharmacy, laboratory services, waste management and finance. Large institutions may require a designated environmental or sustainability officer.

Governance should include a written policy, baseline inventory, measurable targets, annual action plan, assigned responsibilities and senior-management review. Sustainability indicators should be included in departmental performance and capital-purchase decisions.

Staff participation is essential because many environmental impacts arise from routine practices: segregation of waste, switching off unused equipment, appropriate test ordering and stock management. However, programmes should not rely solely on individual goodwill. Systems, procurement contracts and infrastructure must make the environmentally preferable action the easiest safe action.

Energy and greenhouse-gas emissions

Hospitals operate continuously and require dependable power for operating theatres, intensive care, oxygen systems, laboratories, cold chains, ventilation and information systems. Energy audits should measure total electricity and fuel consumption, peak demand, generator use and consumption by major systems.

Initial measures include preventive maintenance, LED lighting, occupancy controls, efficient motors, temperature optimization and correction of steam or compressed-air leaks. Heating, ventilation and air-conditioning systems are major users, but reductions in air changes or filtration must not compromise infection prevention or occupational safety.

On-site solar systems can lower emissions and improve resilience when combined with appropriate storage and maintenance. Renewable electricity contracts may offer additional benefits. Diesel generators should remain emergency backups rather than routine power sources.

Anaesthetic gases deserve specific attention. Desflurane and nitrous oxide have substantial climate effects. Avoiding desflurane where clinically appropriate, using low fresh-gas flows, maintaining gas systems and preventing nitrous-oxide leakage can achieve rapid reductions without compromising care. Clinical decisions must remain individualized; environmental preference should never override patient safety.

Water, sanitation and wastewater

Hospitals require reliable water for hygiene, sterilization, dialysis, laboratories, cooling, laundry and food preparation. Green auditing should quantify water drawn from each source, consumption per occupied bed or service unit, leakage, wastewater generation and treatment performance.

Water-saving fixtures, leak detection, efficient laundry practices and rainwater harvesting can reduce freshwater demand. Treated wastewater may be reused for landscaping, flushing or cooling where regulations and microbiological controls permit. Reuse for clinical purposes requires more stringent safeguards.

Water conservation should never undermine hand hygiene, sanitation or infection prevention. In water-scarce settings, the priority is secure access to adequate safe water before pursuing reductions in clinically necessary use.

Waste and circular resource use

Health-care waste includes general municipal-type waste, infectious waste, sharps, pharmaceutical waste, chemical waste, radioactive waste, electronic waste and pathological material. Poor segregation causes low-risk waste to enter expensive hazardous-waste streams and exposes workers to injury and infection.

The waste hierarchy prioritizes prevention, reduction, safe reuse where permitted, recycling, recovery, treatment and final disposal. Procurement of products with reduced packaging, inventory control and prevention of medicine expiry can reduce waste before it is generated.

Reusable devices can have lower life-cycle impacts than disposable alternatives, but this is not universal. Outcomes depend on manufacturing, transport, sterilization, local electricity and water, number of reuse cycles and infection-control requirements. Product decisions should therefore use life-cycle evidence rather than assumptions that "reusable" or "single-use" is always preferable.

Waste audits should assess generation by category and department, segregation accuracy, container placement, barcoding, internal transport, worker protection, storage, treatment and final disposal. Incineration should be limited to waste categories that genuinely require it, because unnecessary incineration increases emissions and costs.

Sustainable procurement and pharmaceuticals

Procurement is a major but frequently neglected lever. Tender specifications can require suppliers to disclose environmental performance, reduce packaging, take back products, avoid hazardous chemicals and provide repairable or reusable equipment.

Lowest purchase price should not be the only criterion. Total cost of ownership includes energy, consumables, maintenance, lifespan and disposal. A cheaper device that requires frequent replacement may be financially and environmentally inferior.

Pharmaceutical footprints arise from manufacturing, packaging, distribution, refrigeration, use and disposal. Rational prescribing, generic use where clinically appropriate, prevention of stock expiry and safe return systems can reduce harm. Sustainability should support—not distort—evidence-based medicine.

Transport, food and campus environment

Staff, patient, visitor, ambulance and supplier travel can contribute substantially to local pollution and emissions. Hospitals can promote public transport, shuttle services, walking, cycling, carpooling, electric vehicles and teleconsultation where clinically appropriate.

Hospital food systems influence both health and environmental impact. Procurement can emphasize nutritionally appropriate, seasonal and locally available foods while reducing avoidable food waste. Changes must respect clinical diets, cultural preferences, affordability and nutritional adequacy.
Trees, shaded walkways, green roofs and permeable surfaces can reduce heat, improve storm-water management and support patient well-being. Tree counts alone, however, are poor measures of sustainability if species selection, survival, water requirements and ecological suitability are ignored.

Green Audit: Scope and Methodology
A credible green audit begins by defining organizational and operational boundaries. Auditors must specify whether the exercise covers one building, an entire campus, outsourced services, staff travel and supply-chain impacts. Without clear boundaries, performance cannot be compared over time.
The first stage is document review: utility bills, fuel logs, procurement records, waste manifests, water-quality reports, equipment inventories, environmental permits and disaster plans. The second is physical inspection of wards, theatres, laboratories, kitchens, laundries, pharmacies, stores, boiler rooms, waste areas and sewage-treatment systems.
Data should be normalized using denominators such as occupied bed-days, outpatient visits, surgical procedures or floor area. Absolute reductions are essential for climate targets, but intensity measures help distinguish improved efficiency from reduced service volume.
Carbon accounting should follow recognized greenhouse-gas principles and report scopes separately. Facilities beginning the process may first measure energy, fuel, refrigerants, anaesthetic gases, waste and travel before progressively incorporating procurement and pharmaceuticals.
The audit report should classify findings by legal compliance, patient or worker risk, environmental impact, cost, feasibility and implementation time. Corrective actions may be divided into immediate no-cost measures, short-term operational improvements and long-term capital investments.
Green auditing should be integrated with infection control, biomedical waste audits, fire safety, occupational health, disaster preparedness and quality accreditation. Parallel inspections conducted by separate teams can produce duplication and contradictory recommendations.

Measuring Performance and Avoiding Greenwashing
Hospitals frequently publicize isolated achievements—solar installations, plastic bans or plantation drives—without reporting total emissions, procurement or service-adjusted resource use. Such claims may constitute greenwashing when they imply comprehensive sustainability without supporting data.
Performance reports should include baseline year, audit boundary, methodology, absolute and intensity indicators, targets, progress and unresolved gaps. Carbon offsets should not substitute for direct reductions. Tree planting cannot compensate reliably for continued fossil-fuel consumption, particularly when long-term survival and carbon storage are uncertain.
Certification can motivate improvement and provide external recognition, but certification standards vary. Some emphasize building design, others operational performance. A highly rated new building may still deliver resource-intensive care, while an older hospital may achieve substantial operational improvements without expensive architectural redesign.
The audit should therefore evaluate both environmental performance and clinical value. Reduced energy use is not a success if wards become dangerously hot. Reduced water use is not beneficial if sanitation deteriorates. Waste reduction is unsafe if contaminated products are reused without validated reprocessing.

Evidence for Environmental and Economic Benefits
Life-cycle assessment has become an important tool for comparing environmental impacts across products and clinical processes. A review of 43 hospital-based life-cycle studies found that such assessments can identify environmental hotspots and support management decisions, although methods and outcome indicators varied substantially.[4]
Many case studies report cost savings from energy efficiency, improved segregation, lower anaesthetic-gas use and waste prevention. However, publication bias is likely because successful projects are more often reported. Capital costs, staff time, maintenance and unintended consequences are inconsistently included.

Table 1. Proposed Green-Hospital Audit Framework

Audit domain	Core indicators	Examples of corrective action	Important safeguards
Governance	Green policy, committee, responsible officer, annual targets, staff training and public reporting	Establish multidisciplinary green team and board-level review	Avoid symbolic committees without authority, data or budget
Carbon inventory	Scope 1, 2 and material Scope 3 emissions; emissions per bed-day or service unit	Create baseline, identify hotspots and set time-bound targets	Report boundaries and assumptions; do not compare unlike facilities
Energy	kWh consumed, peak demand, energy-use intensity, generator fuel and renewable share	LEDs, efficient HVAC, maintenance, solar power and storage	Maintain critical power, ventilation, temperature and infection control
Water	Total use, use per occupied bed, leakage, rainwater capture and wastewater reuse	Leak repair, low-flow fixtures, metering and rainwater harvesting	Do not restrict clinically required water or hand hygiene
Waste	Waste by category, segregation error, recycling rate, incinerated waste and sharps injuries	Source segregation, staff training, composting and authorized recycling	Comply with biomedical, chemical, radioactive and e-waste regulations
Procurement	Environmental criteria in tenders, packaging, product lifespan and supplier reporting	Life-cycle procurement, take-back clauses and reduced packaging	Environmental criteria must not compromise quality or availability
Pharmaceuticals	Expired stock, return systems, high-impact products and rational use	Improve inventory control, safe disposal and evidence-based prescribing	Avoid medicine substitution without clinical evidence
Operating theatres	Anaesthetic gases, energy, procedure packs and reusable or disposable products	Low-flow anaesthesia, avoid desflurane when suitable and optimize packs	Preserve sterility and individualized anaesthetic safety
Food	Sustainable procurement, nutritional quality and food-waste generation	Menu planning, portion review, composting and local procurement	Ensure adequate nutrition, food safety and cultural acceptability
Transport	Staff and patient travel, fleet fuel, parking and telehealth use	Public transport, shuttles, carpooling, cycling and electric fleets	Telemedicine must be clinically appropriate and digitally equitable
Indoor environment	Air quality, thermal comfort, daylight, noise and hazardous chemicals	Ventilation maintenance, low-toxicity materials and noise control	Energy savings must not worsen indoor air quality
Climate resilience	Heat, flood, storm, drought and supply-chain risk assessments	Cool roofs, flood protection, backup water and energy, emergency stocks	Test plans through drills and include vulnerable patients and workers
Green campus	Tree survival, biodiversity, shade, permeable area and storm-water management	Native planting, shaded routes and ecological landscaping	Avoid invasive species and water-intensive ornamental planting
Quality and health outcomes	Infection rates, occupational injuries, patient comfort, service disruption and cost savings	Link sustainability actions with quality dashboards	Environmental gains should not be claimed without verifying health effects

Environmental interventions may improve health directly through cleaner air, reduced toxic exposure, better thermal comfort and reliable power and water. Some interventions also strengthen patient safety: solar-backed cold chains, resilient oxygen systems and flood-proofed infrastructure can maintain care during disasters.

Evidence linking whole-hospital green certification with patient mortality, infection, staff retention or population health remains limited. The strongest evidence often relates to specific operational interventions rather than the "green hospital" label itself.

Public Health Significance

Health-care decarbonization produces benefits beyond hospital campuses. Reduced fossil-fuel use lowers particulate and nitrogen-oxide pollution. Sustainable food procurement can model healthy diets. Responsible purchasing can influence manufacturers and supply chains.

Hospitals also hold moral authority. A health system that treats climate-sensitive disease while contributing unnecessarily to emissions risks institutional inconsistency. Environmental stewardship is therefore connected to the ethical principle of avoiding harm.

Climate resilience is particularly important because hospitals must remain functional when communities are most vulnerable. Extreme heat can overload cooling and electricity systems, floods can isolate facilities, and drought can compromise sanitation. Green and resilient design should be viewed as essential preparedness rather than optional corporate responsibility.

Indian Perspective

India must expand health-care access while responding to severe heat, floods, air pollution, water scarcity and energy insecurity. Its pathway cannot simply replicate carbon-intensive hospital development followed by costly retrofitting.

Under the National Programme on Climate Change and Human Health, the National Centre for Disease Control released Guidelines for Green and Climate Resilient Healthcare Facilities in 2023, guidance on solar powering health facilities and a national hospital energy-consumption survey. A Green and Climate-Resilient checklist and updated guidebook provide a basis for facility-level assessment.[5]

The Indian framework emphasizes energy efficiency, renewable power, water conservation, waste management, climate-sensitive design, emergency preparedness and workforce capacity. The Indian Public Health Standards 2022 also incorporate elements relevant to resilient and resource-efficient infrastructure.

Kayakalp has strengthened attention to cleanliness, infection control, sanitation and waste management in public facilities. Its experience shows that structured assessment, peer review and recognition can mobilize change. However, cleanliness scores should not be assumed to measure greenhouse-gas emissions, water efficiency or climate resilience.

The National Accreditation Board for Hospitals and Healthcare Providers has also introduced a voluntary climate-change resilience and sustainability initiative. Accreditation can mainstream sustainability in private and public hospitals, but smaller facilities will require technical assistance and affordable measurement tools.

Indian implementation faces several constraints: unreliable metering, fragmented utility records, outsourced services, limited capital, insufficient engineering staff and competing clinical priorities. Many hospitals remain focused on statutory biomedical-waste compliance rather than broader environmental performance.

Climatic diversity requires local adaptation. Himalayan hospitals need reliable winter energy, landslide preparedness and waste solutions suited to difficult transport. Coastal facilities need cyclone and flood resilience, while hot and arid regions require passive cooling and secure water systems. A single building template would be inappropriate.

Recent Advances

Recent practice increasingly focuses on net-zero clinical pathways rather than buildings alone. Carbon accounting is being incorporated into procurement, clinical guidelines and health-technology assessment. Life-cycle analysis can compare alternative devices, procedures and care models when health outcomes are equivalent.

Smart meters, building-management systems and artificial-intelligence-assisted energy forecasting may identify abnormal consumption and optimize cooling. These tools are useful only when data are reliable and technical teams can act on alerts.

Microgrids combining solar generation, battery storage and grid supply can improve both sustainability and resilience. Their design must prioritize critical services and include maintenance, replacement and end-of-life battery planning.

Low-carbon operating theatres are another major area of innovation. Initiatives include rational instrument packs, reusable textiles where safe, better waste segregation, low-flow anaesthesia and reduction of unnecessary standby energy. Operating theatres are highly resource intensive, but environmental changes require close collaboration with infection-control and surgical teams.

Climate-risk assessment is also moving from generic disaster plans to hazard-specific analysis. Facilities increasingly evaluate heat thresholds, flood levels, water availability, supply-chain dependency and vulnerability of patients, staff and essential equipment.

Challenges and Limitations

A major limitation is the absence of standardized, universally applicable green-audit methodology. Facilities use different boundaries, emission factors and denominators. Comparisons may therefore reward hospitals that exclude supply chains or outsourced activities.

Data quality is often poor. Utility bills may cover several buildings, waste may be weighed inconsistently and procurement databases may not contain environmental information. Precise carbon accounting can require expertise unavailable to smaller facilities.

Another challenge is the tension between sustainability and infection prevention. The COVID-19 pandemic increased single-use products and waste. Some disposable items are clinically necessary, while others persist because of habit, liability concerns or industry influence. Decisions require risk assessment rather than ideological preference.

Rebound effects are possible. Financial savings from efficiency may fund additional resource consumption, and digital systems may add energy use even while reducing travel. These effects should be measured.

Equity is central. Requiring low-income health systems to meet costly net-zero standards without international support could delay essential infrastructure. Fair pathways should allow necessary expansion of high-value care while high-emitting systems undertake faster absolute reductions.[6]

Finally, environmental performance is rarely linked to clinical outcomes. Hospitals need evidence that proposed measures preserve or improve safety, quality and access. Environmental benefit should become an additional dimension of value, not a replacement for health outcomes.

Future Directions

Green audits should evolve into standardized environmental-quality systems with core indicators, independent verification and annual public reporting. A minimum dataset could include energy, fuel, water, waste, renewable share, anaesthetic gases, procurement and climate-disruption events.

India should develop facility benchmarks by level of care, climate zone and service profile. Comparing a tertiary teaching hospital with a rural primary health centre using the same intensity target would be misleading.

Research should prioritize prospective evaluations of interventions in Indian hospitals, including costs, emissions, resilience, infection control and patient outcomes. Multicentre life-cycle studies are needed for commonly used devices, surgical packs, dialysis, laboratory testing and hospital food systems.

Environmental criteria should be integrated into procurement portals and health-technology assessment. Manufacturers should provide standardized product carbon, repairability, packaging and end-of-life information.

Training in sustainable health care should enter medical, nursing, public-health, engineering and hospital-administration curricula. Departments need protected time and practical improvement skills, not awareness lectures alone.

Capital investment should prioritize interventions that simultaneously improve resilience, health and financial performance: reliable renewable energy, efficient cooling, safe water, flood protection and clean transport. Climate finance and concessional lending may be essential for public-sector facilities.

Most importantly, prevention and high-value care should become central to sustainability. Avoiding an unnecessary admission or investigation frequently saves more resources than improving the efficiency of the same low-value activity.

CONCLUSION

Green hospitals are not defined by isolated technologies or architectural labels. They are health-care organizations that deliver safe, equitable and effective services while minimizing pollution, resource depletion and greenhouse-gas emissions and remaining functional during climate disruption.

A rigorous green audit provides the foundation for this transition. It should examine governance, energy, water, waste, procurement, pharmaceuticals, transport, food, indoor environment, climate resilience and clinical practice. The audit must produce measurable corrective actions and be repeated as part of institutional quality improvement.

The evidence supports many practical interventions, but important gaps remain regarding standardized measurement, indirect emissions, costs and patient outcomes. Sustainability claims should therefore remain transparent and proportional to the evidence.

India has established an important policy foundation through national green and climate-resilient health-facility guidance, solarization initiatives, accreditation programmes and quality platforms. The next challenge is implementation across diverse climates and levels of care.

The guiding principle should be simple: health care must not compromise patient safety or equitable access, but neither should preventable environmental harm be accepted as an unavoidable cost of healing. A genuinely green hospital protects present patients, future populations and the ecological systems on which all health depends.

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