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Review Article

Sustainable energy and water management in green hospitals: a narrative review

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ABSTRACT

Hospitals consume substantial amounts of energy and water, while intensive care units (ICUs) have high resource demands because life-support equipment, monitoring systems and heating, ventilation and air conditioning operate continuously. This narrative review examines hospital and critical-care environmental impacts, sustainable energy and water management, healthcare workers' knowledge and practices, and the use of Plan-Do-Study-Act (PDSA) cycles. Literature and guidance were identified through PubMed/MEDLINE, PubMed Central, Google Scholar, publisher databases and relevant health-agency and professional-society websites, and findings were synthesised thematically. The reviewed evidence identifies building energy, especially HVAC, and clinical consumables as major environmental hotspots. Water conservation must be planned alongside infection prevention and essential hygiene. Healthcare workers often express environmental concern but lack practical training, infrastructure and organisational support. Education combined with prompts, checklists, audit and feedback, local champions and leadership support is more likely to translate awareness into routine practice. The review also describes a 45-day quality-improvement project involving 80 staff members in ICUs at a hospital in Gurugram, India. Following two PDSA cycles, knowledge scores and observed practice adherence improved. In a descriptive comparison of one pre-intervention month with one post-intervention month, electricity use per occupied bed decreased by 17.7%, diesel use by 54.9% and water use per occupied bed-day by 11.25%. Because the project had no concurrent control group and compared only one month before and after the intervention, these changes cannot be attributed conclusively to the intervention. Longer time series, patient-safety balancing measures and transparent carbon accounting are needed to assess whether improvements are sustained.

Keywords: Green hospital, Energy management, Water management, Environmental sustainability, Intensive care unit, Plan-do study act, Quality improvement, India

INTRODUCTION

Healthcare protects health but also contributes to the environmental pressures that threaten it. Health care accounts for about 5% of national carbon footprints across the countries studied, and a global multi-region assessment found that it also contributes substantially to air pollutants and scarce water use.[1,2] In the United States, the health care sector was responsible for about 10% of national greenhouse gas emissions.[3] Health systems have responded with decarbonisation commitments, most prominently the NHS net zero strategy, and the WHO has published guidance and an operational framework for climate-resilient and environmentally sustainable health care facilities built on safe water and sanitation, sustainable energy services, a capable workforce and resilient infrastructure.[4,5-7]

Hospitals are the largest contributors to this footprint within the health sector, and building energy and medical

consumables are recurring hotspots.[8] A "green hospital" is one that reduces its environmental impact through efficient use of energy and water, waste reduction, sustainable procurement and a resilient built environment, while maintaining or improving the quality of care.[5,9] Within hospitals, the ICU is an environmental hotspot. Life-support systems, monitors, infusion pumps, dialysis machines, imaging and HVAC operate 24 hours a day, and ICU patients consume large quantities of single-use materials.[10-12] A life-cycle assessment in a large US hospital estimated that an ICU bed-day generated about three times the greenhouse gas emissions of an acute ward bed-day.[13] Recognising this, the European Society of Intensive Care Medicine (ESICM) published a Green Paper setting out priorities for reducing the environmental impact of critical care, and the Society of Critical Care Medicine established a sustainability task force.[14,15]

Policy guidance alone does not change practice at the bedside. Healthcare workers report concern about the environment but limited knowledge, training and organisational support to act on it.[16,17] Many day-to-day decisions about switching off lights and idle equipment, managing room temperature, using taps and reporting leaks are made by nurses, technicians and support staff. Nurses in particular are increasingly recognised as agents for environmentally sustainable health systems.[18,19]

Quality improvement methods offer a practical way to translate sustainability goals into bedside practice. The PDSA cycle, the core of the Model for Improvement, allows teams to test small changes, measure their effect and adapt them.[20] It has been used successfully in Indian hospitals to improve practices such as hand hygiene.[21] Yet evidence on staff-led, PDSA-based energy and water stewardship in hospitals, and in ICUs in particular, remains scarce, especially in India.

This narrative review therefore aims to summarise the environmental footprint of hospitals and critical care, with emphasis on energy and water; review strategies for sustainable energy and water management in green hospitals, with particular attention to ICUs, and the factors that influence staff behaviour; examine PDSA cycle as an implementation method; and illustrate these principles with a PDSA-based energy and water stewardship project conducted in the ICUs of a hospital in Gurugram, India.

Review published evidence under 5 themes-environmental footprint of hospitals and critical care, energy management, water management, staff knowledge and behaviour and PDSA cycle as an implementation method.

ENVIRONMENTAL FOOTPRINT OF HOSPITALS AND CRITICAL CARE

Carbon footprint and hotspots

A systematic review of the carbon footprint of critical care found wide variation in reported estimates, reflecting differences in methods, system boundaries and settings, but consistently identified energy use, consumables and equipment as major contributors.[11] In a comparison of the treatment of septic shock in US and Australian ICUs, emissions were about 178 and 88 kg CO_2-equivalent per patient-day respectively, and energy use, mostly for HVAC, made up 87% and 76% of these totals.[21,22] A Dutch study of circular material flow estimated about 12 kg CO2-equivalent, 17 kg of materials and 300 L of water per ICU patient per day attributable to materials, with gloves, gowns, bed liners, masks and syringes as hotspots.[12] At the hospital level, building energy and medical consumables are recurring hotspots.[8] Recent reviews of sustainable intensive care describe three broad areas for action: energy and buildings, materials and waste, and clinical practice.[23-25]

Energy in Indian hospitals

In India, a national hospital energy consumption survey by the NCDC analysed 341 hospitals and reported energy use in medical college hospitals of 756-2,753 kWh per bed per year; 60% of the hospitals relied on direct-expansion air conditioning.[26] A study in a South Indian hospital found that staff were aware of energy-saving measures but practised them poorly, and recommended a formal energy management programme.[27] Frequent reliance on diesel generators for backup power adds to both cost and emissions. The NCDC Guidelines for Green and Climate Resilient Healthcare Facilities identify energy efficiency and water management as priority areas for greening Indian health facilities, and global guidance stresses that reliable electricity is itself a prerequisite for safe care.[9,28]

Water use

Hospitals are large water consumers. A systematic review of hospital water indicators reported consumption of 103-458 m³ per bed per year, equivalent to about 280-1,250 L per bed per day, and highlighted the lack of standard indicators.[29] Water is used for hand hygiene, patient bathing, cleaning, sterilisation, laundry, food services, HVAC cooling and haemodialysis. Haemodialysis is particularly water-intensive, and reuse of reverse-osmosis reject water and spent dialysate has been proposed within a circular-economy approach.[30] Indicators that use occupied bed-days as the denominator allow resource intensity to be tracked over time and compared between periods.[31]

ENERGY MANAGEMENT IN GREEN HOSPITALS AND ICUS

Energy management in green hospitals spans infrastructure measures and staff behaviour, and the ICU, with its continuous equipment and HVAC load, is a priority area. Infrastructure measures include efficient HVAC with setback during periods of low occupancy, LED lighting, occupancy sensors and efficient medical equipment.[14] These require capital investment and

engineering input.[23,24] Behavioural measures, in contrast, are low-cost and within the control of ICU staff: switching off lights in unoccupied areas and during the day where natural light is adequate; switching off or placing in standby equipment that is not in use and is not required for patient safety, such as computers, spare monitors, chargers, warmers and televisions; keeping doors and windows closed to maintain the HVAC envelope and reporting temperature or airflow problems; identifying and reporting faulty equipment and "phantom" standby loads; consolidating the use of shared equipment and avoiding unnecessary portable heaters and fans.

Staff-centred energy conservation campaigns in hospitals can reduce consumption, but savings depend on the building, its services and the department, so campaigns should be tailored to the setting.[32] An energy-saving behaviour intervention in two English hospitals reduced energy use and carbon emissions and was associated with a quieter environment for patients.[33] Safety boundaries must be explicit: equipment needed for monitoring, resuscitation, infection control or patient comfort must never be switched off in the name of conservation, and such rules should be written into the checklists that staff use.

WATER MANAGEMENT IN GREEN HOSPITALS: BALANCING CONSERVATION AND INFECTION PREVENTION

Water management in hospitals, and in critical care in particular, is more complex than energy stewardship because water is integral to infection prevention. WHO and UNICEF report that only about half of health care facilities worldwide have basic hygiene services, and hand hygiene must not be compromised by conservation messages.[34] Stewardship efforts in the ICU should therefore target waste rather than essential use, for example: closing taps fully and avoiding taps left running during tasks; reporting leaks, dripping taps and faulty flush systems promptly; avoiding unnecessary flushing and rinsing, and using appropriate volumes for cleaning and optimising dialysis water systems in collaboration with engineering teams.

At the same time, hospital water systems are recognised reservoirs of multidrug-resistant organisms. A systematic review found 32 reports over 20 years of carbapenem-resistant organisms transmitted from the hospital water environment, particularly sinks and drains; outbreaks were controlled in most reports, but the organism was eliminated from the water environment in only about a third.[35] In a Dutch ICU, removing sinks from patient rooms and introducing "water-free" patient care was associated with a reduction in ICU-acquired gram-negative colonisation.[36] These findings show that reducing unnecessary water use can be aligned with infection prevention, but any change in water practices should be developed jointly with the infection prevention and control team and monitored for unintended effects.

STAFF KNOWLEDGE, ATTITUDES AND BEHAVIOUR

Surveys across health systems report a consistent pattern: most healthcare workers are concerned about the environmental impact of health care, but formal training, knowledge of practical actions and organisational support are limited. In South Africa, healthcare professionals expressed concern but reported low knowledge and limited implementation of sustainable practices.[16] Australian healthcare workers identified lack of time, knowledge, leadership and infrastructure as barriers.[17] Nursing research identifies education, leadership, green teams and organisational support as key enablers, and a scoping review of hospital sustainability indicators found that many indicators relate directly or indirectly to nursing work.[18,19,31]

Behaviour change theory explains why awareness alone rarely changes practice. The COM-B model holds that behaviour requires capability, opportunity and motivation, and the Behaviour Change Wheel links these to intervention functions such as education, training, environmental restructuring (for example, prompts on switches and taps), persuasion, incentivisation and enablement.[37] Audit and feedback produce small to moderate improvements in professional practice, with a median absolute improvement in compliance of 4.3% and larger effects when baseline performance is low and feedback is repeated.[38] In a systematic review of educational interventions on waste management among healthcare workers, education improved knowledge, attitudes and practices.[39] Together, these findings support multicomponent interventions that combine education with prompts, checklists, feedback, champions and accountability.

THE PDSA CYCLE AS AN IMPLEMENTATION METHOD

The PDSA cycle is the testing component of the Model for Improvement, which asks what the team is trying to accomplish, how it will know that a change is an improvement and what changes can be made that will result in improvement.[20] In the Plan phase the team defines the objective, predicts the result and plans data collection; in the Do phase it carries out a small-scale test; in the Study phase it compares the data with predictions; and in the Act phase it adopts, adapts or abandons the change and plans the next cycle.

PDSA is well suited to ICU sustainability because the problem is context-specific, involves several staff groups and requires iterative adjustment. Its application in health care, however, is often weak. A systematic review of 73 PDSA studies found that fewer than 20% documented iterative cycles fully and only 15% used data at monthly or more frequent intervals.[40] A later review of 120 PDSA projects found that although 98% reported improvement, only 27% met a specific quantitative aim and only 4%

adhered to all key PDSA features.[41] PDSA cycles are frequently reduced to single before-after tests, when the method's strength lies in sequential, small, rapidly measured cycles supported by organisational infrastructure.[42] The SQUIRE 2.0 guidelines recommend that QI reports describe the rationale, context, intervention and methods used to study it, so that readers can judge how far results can be attributed to the change.[43]

LITERATURE SEARCH AND SELECTION

This is a narrative review. Literature was identified through PubMed/MEDLINE, PubMed Central, Google Scholar and publisher databases, supplemented by the websites of the WHO, the National Centre for Disease Control (NCDC) of India, and professional critical care societies. Search terms combined "hospital", "green hospital", "intensive care" or "critical care" with "carbon footprint", "environmental sustainability", "green ICU", "energy", "electricity", "HVAC", "water", "stewardship", "knowledge, attitude and practice", "behaviour change", "audit and feedback" and "Plan-Do-Study-Act" or "quality improvement". English-language publications from 2011 to 2026 were prioritised; seminal earlier works on methodology were also included. Systematic and narrative reviews, life-cycle assessments, original studies, QI reports and policy guidance were eligible. The reference lists of key reviews were hand-searched.

Data extraction and synthesis

For each included study, the design, setting, focus and principal quantitative finding were extracted. Because the studies differed widely in design, setting and outcome measures, meta-analysis was not appropriate, and the evidence was synthesised narratively under the five themes of the review. The key studies are summarised in Table 1.

Illustrative quality improvement project

A prospective QI project was carried out in selected ICUs of a hospital in Gurugram, Haryana, India, over 45 days in two consecutive PDSA cycles. Staff were assessed at baseline, after each cycle and at the end of the project. Eighty staff took part: 50 nurses (62.5%), 15 technicians (18.75%) and 15 general duty assistants (GDA) or housekeeping staff (18.75%). Staff on temporary contracts or extended leave and those with less than six months of ICU experience were excluded. Written informed consent and institutional ethics committee approval were obtained.

In the first Plan phase, baseline knowledge, practices and utility indicators were reviewed to identify gaps. The Do phase combined education and demonstration, posters, reminders placed at switches and water taps, a practical energy and water checklist, audit and feedback, peer accountability and energy and water stewardship champions. The Study phase reassessed knowledge, observed practices and utility indicators. In the Act phase, areas of difficulty were identified and used to guide reinforcement and monitoring in the second cycle.

Knowledge was measured with a structured questionnaire and practice with an observational checklist covering energy saving, water saving, optimisation and reporting. The tools were validated by seven experts in hospital administration, quality improvement/patient safety and medicine/nursing (S-CVI=1). Test-retest reliability (Karl Pearson's r) was 0.93-0.95 for the knowledge questionnaire and 0.86-0.93 for the practice checklist. Utility data were obtained from institutional records and expressed per occupied bed.

SYNTHESIS OF THE LITERATURE

Table 1 summarises the key studies identified in the review. Six principal findings emerged.

Hospitals and ICUs have a substantial and measurable footprint. Health care accounts for about 5% of national carbon footprints and about 10% of greenhouse gas emissions in the United States.[1,3] Within hospitals, building energy and consumables are recurring hotspots, and an ICU bed-day generates about three times the emissions of a general ward bed-day.[8,13]

Energy, largely for HVAC, dominates the ICU footprint. Energy accounted for 87% and 76% of the carbon footprint of ICU care for septic shock in the United States and Australia, respectively.[22]

Energy and water use vary widely, and Indian data are scarce. Energy use in Indian medical college hospitals ranged from 756 to 2,753 kWh per bed per year, and hospital water use ranged from 103 to 458 m^3 per bed per year internationally.[26,29] The absence of standard indicators limits comparison.[29,31]

Water conservation must be aligned with infection prevention. Hospital water systems and sinks are reservoirs of carbapenem-resistant organisms, and water-free patient care in an ICU was associated with less ICU-acquired gram-negative colonisation.[35,36]

Staff are concerned but lack knowledge and support. Surveys from South Africa, Australia and India consistently report concern about the environment alongside limited knowledge, training and organisational support.[16,17,27]

Multicomponent, iterative interventions are better supported than awareness alone, but QI methods are often poorly applied. Staff-centred energy campaigns can reduce consumption, although savings depend on context.[32,33] Audit and feedback produces modest improvements.[38] Most published PDSA projects do not document iterative cycles or use frequent data.[40,41]

Table 1: Summary of key studies on energy and water management in hospitals and ICUs.

Studies	Design and setting	Focus	Principal finding
Pichler et al 2019[1]	International comparison of national health care footprints	Carbon footprint	Health care accounted for about 5% of national carbon footprints
Eckelman et al 2016[3]	National environmental assessment, United States	Emissions	Health care produced about 10% of national greenhouse gas emissions
Keller et al 2021[8]	Hospital life-cycle assessment	Hotspots	Building energy and medical consumables were major environmental hotspots
McGain et al 2018[22]	Carbon footprint of septic shock care in a US and an Australian ICU	ICU energy	178 vs 88 kg CO_2e per patient-day; energy, mainly HVAC, contributed 87% and 76%
Hunfeld et al 2023[12]	Material-flow analysis, Dutch ICU	Materials and water	About 12 kg CO_2e, 17 kg of materials and 300 L of water per ICU patient-day attributable to materials
Prasad et al 2022[13]	Life-cycle assessment, large US hospital	ICU vs ward	About 138 kg CO_2e per ICU bed-day vs 45 kg per ward bed-day
NCDC, 2023[26]	National hospital energy survey, India (341 hospitals analysed)	Energy use	756-2,753 kWh per bed per year in medical college hospitals; 60% used direct-expansion air conditioning
Billore et al 2018[27]	Hospital, South India	Energy management	Staff were aware of energy saving but practice was poor
Batista et al 2020[29]	Systematic review of hospital water indicators	Water use	103-458 m^3 per bed per year; lack of standard indicators
Gordon et al 2017[35]	Systematic review	Water and infection	32 reports of carbapenem-resistant organisms transmitted from the hospital water environment
Hopman et al 2017[36]	Before-after study, Dutch ICU	Water-free care	Removing sinks reduced ICU-acquired gram-negative colonisation from 26.3 to 21.6 per 1,000 admission-days
Lister et al 2022[16]	Mixed-methods KAP study, South Africa	Staff knowledge	Concern about the environment with limited knowledge and implementation
Loftus et al 2026[17]	Cross-sectional survey, Australia	Staff barriers	Lack of time, knowledge, leadership and infrastructure were the main barriers
Morgenstern et al 2016[32]	Survey of 70 NHS energy managers, England	Staff campaigns	Interest in staff-centred campaigns; savings depend on building and department context
Manika et al 2016[33]	Intervention study in two English hospitals	Energy behaviour	Staff energy-saving intervention reduced energy use and carbon emissions
Ivers et al 2012[38]	Cochrane systematic review	Audit and feedback	Median absolute improvement in compliance of 4.3%
Taylor et al 2014[40]	Systematic review of 73 PDSA studies	QI methodology	Fewer than 20% documented iterative cycles; 15% used monthly or more frequent data
Knudsen et al 2019[41]	Systematic review of 120 PDSA projects	QI methodology	98% reported improvement, but 27% met a quantitative aim and 4% followed all key PDSA features

*KAP-knowledge, attitudes and practices, NCDC-National Centre for Disease Control, QI-quality improvement.

RESULTS OF THE ILLUSTRATIVE QUALITY IMPROVEMENT PROJECT

Knowledge scores increased significantly from baseline in all three staff groups (paired t test, $p<0.05$), with a partial decline in nurses and GDA/housekeeping staff between the first and second post-tests (Table 2). Practice adherence improved after each cycle. At the end of the second cycle, all nurses and technicians and 14 of 15 GDA/housekeeping staff were adherent (McNemar's test, $p<0.001$).

Between the baseline month (April) and post-intervention month (May), electricity uses per occupied bed fell by 17.7%, diesel use by 54.9% and water use per occupied bed-day by 11.25% (Table 3 and Figure 1). Monthly utility cost fell from INR 25,956,595 to INR 21,592,153, while inpatient bed occupancy changed little (25,076 to 25,220).

Table 2: Knowledge and practice outcomes in the Gurugram PDSA project.

Staff group (N)	Knowledge, baseline (mean±SD)	Knowledge, post-test 1	Knowledge, post-test 2	Practice adherent: baseline → cycle 1 → cycle 2
Nurses (50)	7.50±2.92	17.40±3.23	15.28±3.50	0% → 94.0% → 100%
Technicians (15)	8.20±0.94	15.47±0.91	16.80±1.97	20.0% → 86.7% → 100%
GDA/Housekeeping (15)	4.40±2.64	8.13±1.76	7.07±2.05	0% → 73.3% → 93.3%

Table 3: Utility indicators before and after the PDSA cycles (descriptive single-month comparison).

Indicators	April (pre)	May (post)	Absolute change	Relative change
Electricity (units/occupied bed)	3.4930	2.8746	-0.6184	-17.7%
Diesel (L/occupied bed)	11.3	5.1	-6.2	-54.9%
Water (L/occupied bed/day)	32.9	29.2	-3.7	-11.25%
Specific energy cost (INR/sq ft)	34.1237	27.2800	-6.8437	-20.1%
Specific water cost (INR/occupied bed/day)	0.3802	0.3378	-0.0424	-11.2%
Combined monthly utility cost (INR)	25,956,595	21,592,153	-4,364,442	-16.8%

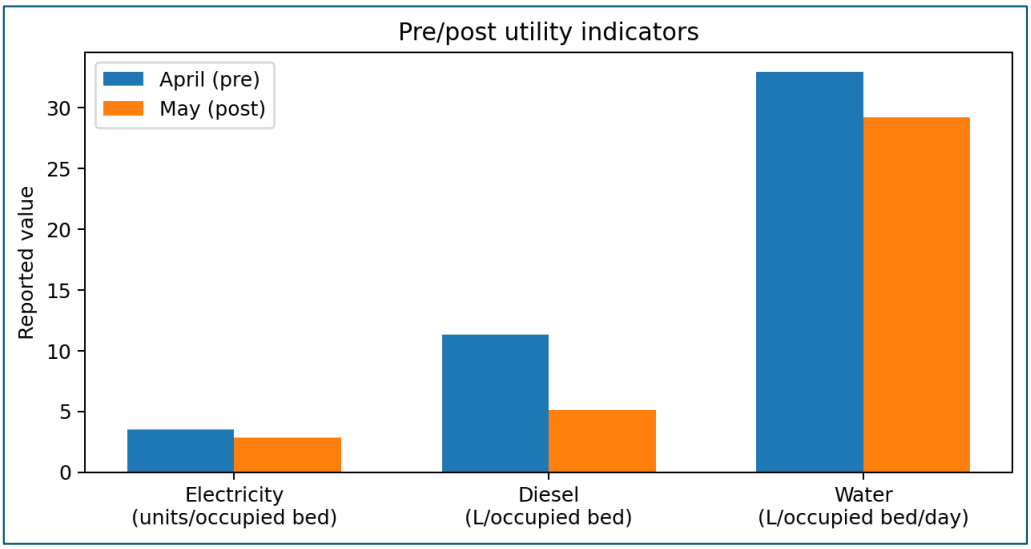


Figure 1: Utility indicators per occupied bed in the baseline month (April) and the post-intervention month (May).

DISCUSSION

Principal findings

This review shows that hospitals, and ICUs in particular, are major consumers of energy and water, that the barriers to sustainable resource management are as much behavioural and organisational as technical, and that structured, iterative quality improvement offers a practical means of change. The Gurugram project illustrates how these principles can be applied in an Indian hospital setting.

Interpretation of the illustrative project

The case illustrates several points from the literature. First, baseline knowledge and practice were low, particularly among GDA and housekeeping staff, which is consistent with surveys showing concern without practical knowledge.[16,27] Second, the multicomponent intervention

combined most of the intervention functions of the Behaviour Change Wheel, and adherence continued to improve in the second cycle, even though knowledge scores declined slightly in two groups.[37] This suggests that environmental prompts, checklists, feedback and champions sustained behaviour beyond what knowledge alone would predict.[38,39] Third, the project included two iterative cycles, with the second informed by the first, which addresses a common weakness of published PDSA projects.[40,41]

The utility results must be interpreted with caution. They compare one baseline month with one post-intervention month, without a concurrent control, and changes in occupancy, patient acuity, equipment use, ambient temperature, maintenance and generator operation could all have contributed. The diesel reduction in particular is likely to reflect the frequency and duration of grid power failures as much as staff behaviour. The water-use figure is also far below the hospital-wide range reported in the literature, which suggests that the metering boundary covered only part of the ICUs' water use.[29] Comparisons with other settings therefore require clearly defined measurement boundaries. The cost difference should be described as a potential saving, and no carbon estimate can be reported without stated emission factors, system boundaries and calculation methods.

A practical framework for PDSA-based energy and water management

Drawing on the literature and the case, Table 4 sets out a framework that hospital units can use, starting with high-intensity areas such as ICUs.

Table 4: Framework for PDSA-based energy and water stewardship in the ICU.

PDSA phase	Key activities	Examples of measures
Plan	Form a multidisciplinary green team (nursing, medical, technicians, housekeeping, engineering, infection control, finance); establish baseline with walk-through audit and utility data; identify hotspots; define safety boundaries; set SMART aims and predictions	Baseline kWh, diesel and water per occupied bed-day; baseline knowledge and practice scores
Do	Education and demonstration; prompts at switches and taps; checklists; champions; peer accountability; engineering fixes for leaks and faulty equipment	Process measures: training attendance, checklist completion, audit frequency
Study	Weekly run charts of utility indicators; observation audits; staff feedback; review of balancing measures	Outcome measures: utility indicators, adherence; balancing measures: hand-hygiene compliance, infection rates, temperature complaints, equipment downtime
Act	Adopt, adapt or abandon changes; target groups with lower adherence; embed changes in standard operating procedures and induction	Sustained performance on run or SPC charts; inclusion in policy

Measurement and evaluation

The literature and the case suggest five principles for evaluating stewardship projects.

Use appropriate denominators and frequent data. Utility indicators should be expressed per occupied bed-day and collected weekly or daily where meters allow, so that changes can be tracked on run charts and, with sufficient data, statistical process control charts.[31,40]

Establish an adequate baseline and follow-up. At least 6-12 months of data before and after implementation, ideally with a concurrent comparison unit or interrupted time-series analysis, are needed to separate the effect of the intervention from seasonality, occupancy and acuity.

Monitor balancing measures. Hand-hygiene compliance, healthcare-associated infections, thermal comfort and equipment availability should be tracked to ensure that conservation does not compromise safety.[14,35]

Report carbon transparently. Carbon estimates should state activity data, emission factors, system boundaries and calculation methods, in line with life-cycle assessment practice in critical care.[11,12]

Assess fidelity and report fully. Training attendance, exposure to reminders, frequency of audit and feedback and champion activity should be documented, and projects should be reported according to SQUIRE 2.0.[43]

Gaps and future directions

Evidence on energy and water management in hospitals, and in ICUs in particular, is still dominated by footprint studies and expert guidance, with few controlled evaluations of interventions. Evidence from low- and middle-income countries, including India, is particularly limited, and no Indian study was identified that evaluated PDSA-based energy and water stewardship in hospital units apart from the case presented here. Hospital-wide programmes that link unit-level stewardship with

infrastructure upgrades, metering and green building certification also need evaluation. Future research should include multicentre projects with longer time series, cost-effectiveness analyses that include capital and staff time, studies of water stewardship that measure infection outcomes, and implementation research on how to sustain behaviour change once project support ends. Integration with national initiatives such as the NCDC guidelines would help scale successful approaches.[9,26]

Limitations

This review has limitations. As a narrative review, it did not follow a formal systematic search protocol or quality appraisal, so relevant studies may have been missed and selection may have been influenced by the authors' judgement. The included studies differed in design, setting, system boundaries and outcome measures, which precluded quantitative pooling. Evidence from low- and middle-income countries was limited. The illustrative project was a single-centre, short-duration, uncontrolled before–after study, and its utility results are descriptive.

CONCLUSION

Hospitals, and ICUs in particular, are major consumers of energy and water, and international and national guidance now calls for green hospitals that manage these resources sustainably without compromising patient safety. The literature shows that staff concern is high but practical knowledge and support are limited, and that multicomponent interventions combining education, prompts, checklists, audit and feedback and champions are more promising than awareness alone. The PDSA cycle provides a structured, iterative way to implement and refine such interventions. Sustainable energy and water management therefore requires both infrastructure investment and staff engagement. The Gurugram project shows that the staff-led approach is feasible in an Indian hospital setting: knowledge improved, practice adherence became near-universal, and utility use per occupied bed fell between the baseline and post-intervention months. Demonstrating sustained and attributable benefit will require longer time series, statistical process control, balancing measures and transparent carbon accounting.

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