Decarbonization initiatives of health-care facilities in Asia: a narrative review

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Objective: Asia's health-care sector is a significant contributor to global greenhouse gas (GHG) emissions, and many facilities are actively engaged in activities to reduce their carbon footprint. While some initiatives are published in peer-reviewed literature, many are only found in institutional or government departmental reports. This study reviews case studies of health-care decarbonization initiatives in Asia from the grey literature to capture insights not represented in peer-reviewed literature.

Methods: Case studies reported by Asian health-care facilities that included measurable environmental footprint and GHG emissions reduction were extracted from the Global Green and Healthy Hospitals (GGHH) and Health Care Climate Learning Initiative databases. A two-stage review process comprised a simple mapping of screened case studies by location and the GGHH sustainability agenda, followed by a more detailed thematic analysis of a subset of studies.

Results: A total of 53 eligible case studies were identified. Most came from health-care facilities in India (n = 14) or Taiwan, China (n = 13). Over half described energy initiatives (n = 30); waste management initiatives also featured highly (n = 21). Thematic analysis of 18 studies identified six key areas: renewable energy, energy efficiency, single-use item elimination, waste management, water conservation and sustainable transportation. Estimations of equivalent GHG emission reductions were mostly reported in relation to purchased electricity.

Discussion: This study highlighted the diversity in Asian health-care decarbonization initiatives and underscored the need for health-care system stakeholders to adopt more systemic solutions and to establish standardized methodologies for measuring emissions from health-care facilities.

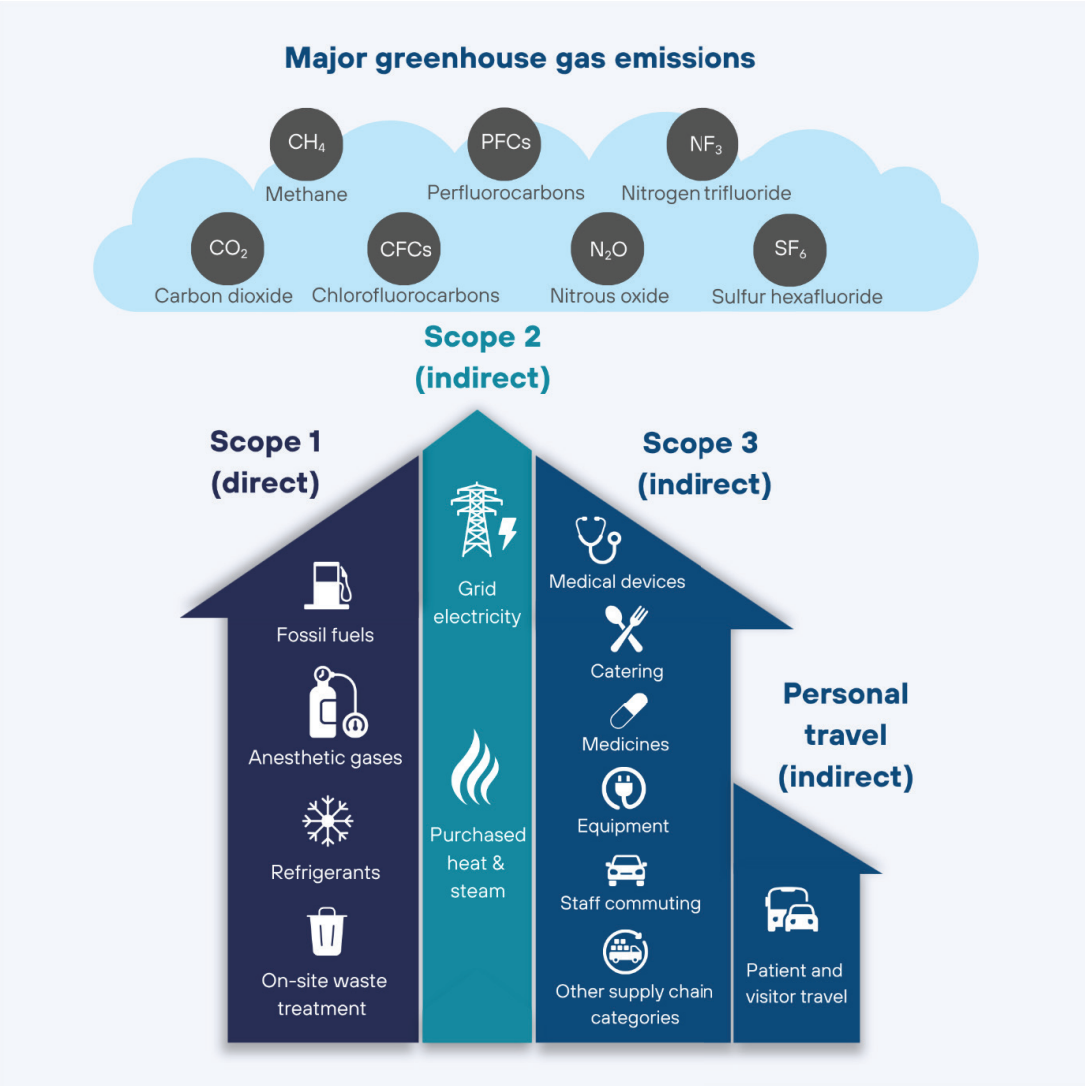
Health-care facilities play a dual role in the climate crisis – they are both affected by and contribute to climate change. Climate change strains health-care facilities and systems by increasing admissions during heat waves and other extreme weather events.[1,2] Conversely, health-care facilities contribute to climate change by emitting greenhouse gases (GHGs); according to current estimates, the health-care sector accounts for 4.4% of global GHG emissions,[3] or (on average) 4.9% of national emissions.[4]

The global health community has recognized this dual challenge, with the World Health Organization (WHO) taking a leading role in promoting climate-resilient and low-carbon health systems globally.[5] Central to this international effort is the Conference of the Parties (COP) process, whereby Member States party to the United Nations Framework Convention on Climate Change meet annually to assess national climate plans and adopt decisions to promote climate action, including emissions reductions.[5] Vulnerability to climate hazards notwithstanding, the health sector is expected to participate in GHG emissions reduction efforts as part of global mitigation strategies.[6]

Monitoring health-care decarbonization requires standardized metrics for GHG emissions measurement and reporting to track progress and evaluate decarbonization initiatives.[7] To this end, and in alignment with adopted GHG Protocols (**Fig. 1**), health-care GHG emissions are categorized into three "scopes": Scope 1 covers direct GHG emissions from facilities; Scope 2 includes emissions from purchased electricity; and Scope 3 comprises indirect emissions from the production and transport of goods and services throughout the supply chain.[8,9] However, in terms of adopting standardized

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Fig. 1. **Scopes of health-care greenhouse gas emissions**



measurement and reporting of emissions, the health sector lags behind most other sectors, such as construction. This is especially true of emissions from medical items and pharmaceuticals, which come under Scope 3.[10]

Given that four Asian countries rank among the world's top 10 health-care carbon emitters,[3] Asia's health-care sector represents a significant contributor to regional GHG emissions.[11] However, existing literature reviews of health-care decarbonization activities have focused largely on Europe and Australia.[12,13] The lack of an Asian perspective in such reviews risks limiting global policy by overlooking region-specific action. In addition, reports of facility-level decarbonization initiatives tend to appear in documents produced by international organizations or governmental departments and other grey literature sources, rather than in peer-reviewed publications.[14] If the grey literature remains outside the evidence base, valuable lessons risk being siloed; moreover, these unexamined initiatives offer potentially valuable decarbonization insights for other health-care settings across Asia and beyond.

Health Care Without Harm (HCWH) is a global organization with regional offices, teams and strategic partners that support health-care systems in reducing their environmental impact.[15] As part of its support role, and working through its Global Green and Healthy Hospitals (GGHH) network, HCWH enables health-care organizations to share their sustainability initiatives in the form of documented case studies.[16] These case study profiles, collated in GGHH's central database, provide a detailed account of each facility's sustainability challenges, initiative implementation, outcomes and lessons learned.

We used these case studies, together with other reports from HCWH's data collections, to conduct a narrative synthesis of facility-level decarbonization activities in Asia. The review aimed to strengthen the evidence base on health sector decarbonization by tapping into the grey literature, highlighting actionable strategies for replication and implementation for health system stakeholders.

METHODS

Data sources

Two HCWH databases were searched. Access to HCWH's GGHH database, which contains 353 case studies on health-care sustainability initiatives from around the world, is restricted to GGHH members. Through a partnership with the HCWH South East Asia (HCWH SEA) Regional Office, access to the GGHH database was granted, and consent requests from health-care facilities to review their case studies were facilitated. HCWH's Health Care Climate Learning Initiative (HCCLI) database, released in 2023 and publicly accessible, comprises 38 case studies on achieving health-care net-zero emissions.[17]

Screening strategy and exclusion criteria

Case studies reported by health-care facilities located in Asia were extracted from the GGHH and HCCLI databases without restrictions on publication year or language. We defined countries or areas in Asia as those classified by HCWH under the Asia and South-East Asia regions in the GGHH member list.[16] Case studies that lacked measurable outcomes for environmental footprint or GHG emissions reductions were excluded. The HCWH SEA Regional Office verified the screening and exclusion process.

Data synthesis

The review was conducted in two stages. In the first stage, studies were mapped by location and by GGHH's 10-item sustainability agenda: leadership, chemicals, waste, energy, water, transportation, food, pharmaceuticals, buildings and purchasing. Each case study could be mapped to up to five GGHH sustainability agenda items, as they often addressed multiple areas or described various actions. Case studies from the HCCLI database, which did not specify which component of the GGHH sustainability agenda they addressed, were assigned categories based on sustainability agenda definitions,[18] with validation from the HCWH SEA Regional Office.

The second stage involved thematic analysis of decarbonization initiatives and their measurable outcomes. The thematic analysis was restricted to case studies for which written consent from the health-care facility was obtained. The analysis process comprised preliminary data familiarization, generating initial codes and identifying themes. The identified themes differed from the above-mentioned 10-item GGHH sustainability agenda and were based on the authors' expertise in sustainable health care, supported by WHO guidance on climate-resilient and environmentally sustainable health-care facilities.[8] The manual analysis was conducted in Microsoft Excel, and coding consistency was ensured through iterative discussions and consensus among the author team.

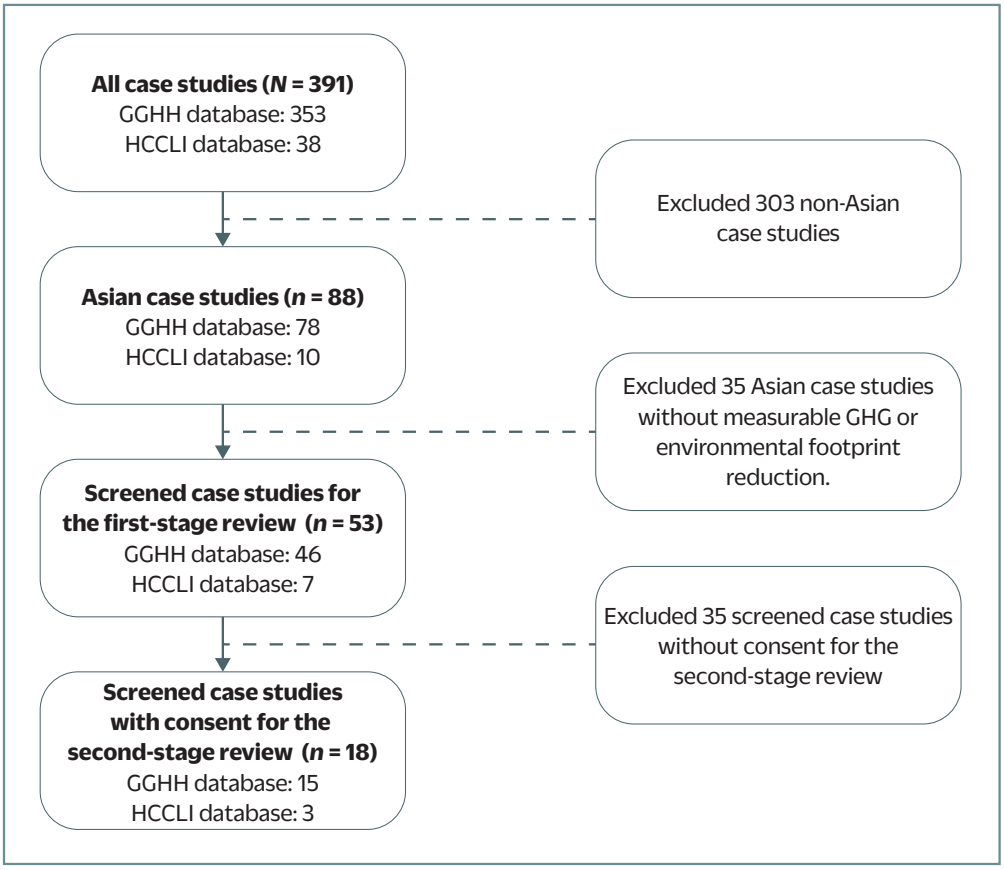
RESULTS

Case study mapping

Our review identified 53 documented decarbonization case studies that were conducted in 38 health-care facilities in Asia and that reported measurable reductions in environmental footprints or GHG emissions (**Fig. 2**). The health-care facilities included hospitals, primary health-care systems, specialized care centres and medical institutes. Case studies originated from China (n = 3); Taiwan, China (n = 13); India (n = 14); Indonesia (n = 2); Malaysia (n = 6); Nepal (n = 4); Oman (n = 1); the Philippines (n = 7); the Republic of Korea (n = 2); and Singapore (n = 1). Case studies from China and Taiwan, China were classified separately in the HCWH database. This distinction affected the mapping results of this narrative review but does not imply a position on territorial status.

Energy and waste initiatives dominated, with 30 of the 53 case studies addressing energy use and 21 targeting the issue of waste. Sustainability agenda

Fig. 2. **Flow diagram of case study inclusion and exclusion criteria**



GGHH: Global Green and Healthy Hospitals; GHG: greenhouse gas; HCCLI: Health Care Climate Learning Initiative.

items such as transportation, food, chemicals, buildings and purchasing were addressed by fewer than 10 case studies, while no studies addressed decarbonization in the pharmaceutical sector. **Fig. 3** shows the distribution of the GGHH sustainability agenda across the 53 included case studies.

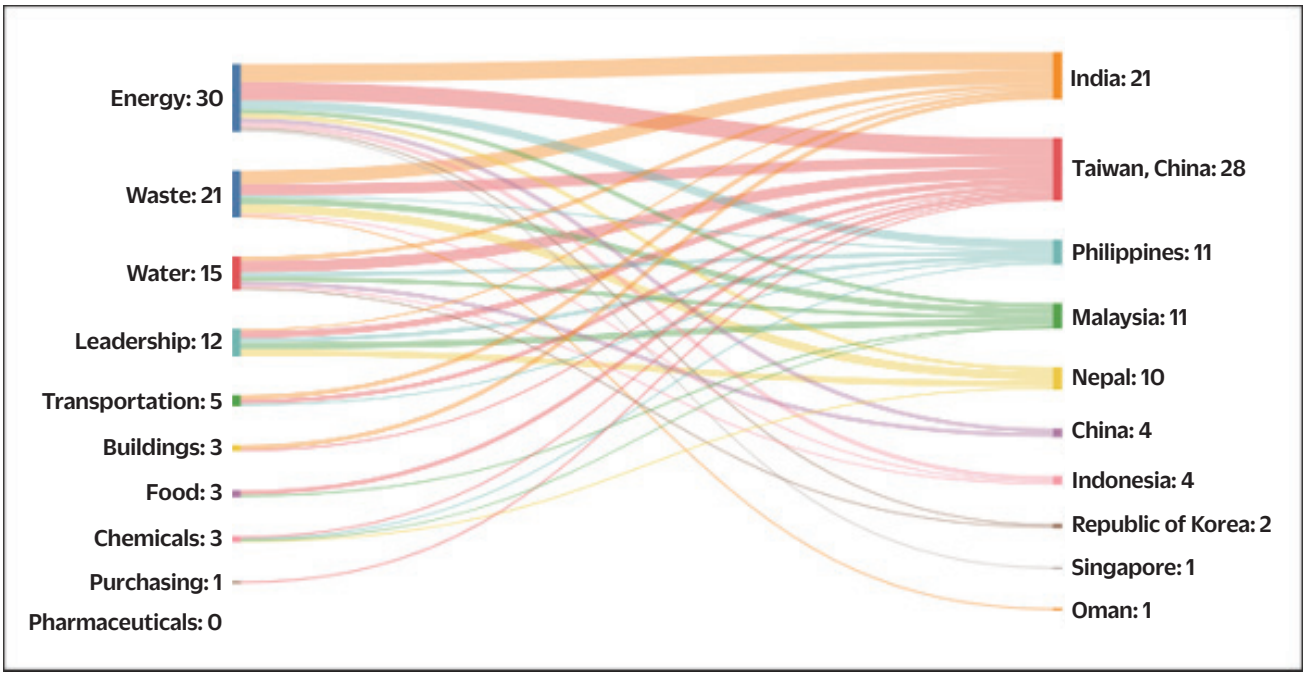
Thematic analysis

We obtained consent for 18 decarbonization studies, which progressed to the thematic analysis review stage (**Fig. 2**). Six key themes were identified: renewable energy, energy efficiency, single-use item elimination, sustainable waste management, water conservation and sustainable transportation. **Table 1** summarizes study characteristics in terms of the decarbonization actions and measurable outcomes, categorized according to these six themes.[19–36] In this subset of case studies, electricity savings from renewable energy and energy efficiency initiatives were most frequently expressed as equivalent reductions in GHG emissions. Other environmental footprint reductions were also translated into GHG equivalents, for example, reduced reliance on waste incineration fuel, single-use plastic bag elimination and bicycle use instead of private cars.

Renewable energy

Use of solar or photovoltaic (PV) panels featured in all three case studies that involved switching to renewable sources of energy. Singapore's Khoo Teck Puat Hospital successfully implemented its PV panel utilization strategy through collaboration with government-authorized service providers.[19] By adopting a leasing model for installing, operating and maintaining PV panels, the hospital reduced its electricity rates while the service provider managed the associated costs. The other two case studies, from Dalin Tzu Chi Hospital in Taiwan, China and Mary Johnston Hospital in the Philippines, showcased the benefits of PV panels equipped with real-time monitoring systems for tracking the amount of energy generated.[20,21]

Fig. 3. **Number of Global Green and Healthy Hospitals sustainability agendas in the screened case studies by agenda type and country or area**



Energy efficiency

The majority of energy efficiency initiatives involved modifying lighting systems to reduce electricity consumption. A case study from Universitas Gadjah Mada Academic Hospital in Indonesia described a pilot project for replacing conventional lighting with light-emitting diode (LED) fixtures in continuously illuminated areas.[22] This initiative informed a transition to full implementation throughout the hospital. A similar initiative was implemented at the Buddhist Tzu-Chi Dialysis Centre in Malaysia, where staff seating arrangements were considered as part of the strategy to replace conventional lights with LED lights while ensuring sufficient lighting levels where needed.[23] The lighting replacement project at the Mary Johnston Hospital in the Philippines was noteworthy because of its comprehensive four-phase process, which included a baseline energy audit, planning, implementation and a final energy audit assessing the impact.[24] The Dalin Tzu Chi Hospital in Taiwan, China took a different approach, enhancing energy efficiency by installing devices such as heat pumps and sensor-activated lighting systems.[20]

Single-use item elimination

Initiatives aimed at reducing single-use items were described in four case studies and demonstrated the broad applicability of such initiatives in health-care settings. The Buddhist Tzu-Chi Dialysis Centre in Malaysia encouraged its staff to bring in vegetarian food in reusable containers as part of its strategy to reduce consumption of single-use plastic items.[25] The centre also adopted digitized systems for dialysis record-keeping, improving efficiency while significantly reducing paper consumption.[26] The case study from Taiwan, China described the Dalin Tzu Chi Hospital's campaign to eliminate disposable utensils and plastic straws as part of a wider initiative to promote eco-friendly practices among its staff and patients.[20] Elimination of single-use personal protective equipment (PPE) was the target of a programme initiated during the COVID-19 pandemic at the Mary Johnston Hospital in the Philippines. In addition to implementing a PPE reprocessing process, which involved segregation, inspection, cleaning, decontamination, tagging and redistribution of reusable PPE, the hospital also developed alternative PPE

Table 1. **Decarbonization initiatives and outcomes in the second-stage review by theme**

Actions	Health-care facilities	Type of measurable environmental footprint reduction	Environmental footprint reduction reported as GHG equivalent
Renewable energy			
• Photovoltaic panel use	• Khoo Teck Puat Hospital, Singapore[19]	• Purchased electricity	• Yes
	• Dalin Tzu Chi Hospital, Taiwan, China[20]	• Purchased electricity	• Yes
	• Mary Johnston Hospital, Philippines[21]	• Not specific (percentage of purchased electricity reduction)	• Yes
Energy efficiency			
• Replacement of fluorescent lights with LED lights	• Universitas Gadjah Mada Academic Hospital, Indonesia[22]	• Purchased electricity	• Yes
	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[23]	• Purchased electricity	• Yes
	• Mary Johnston Hospital, Philippines[24]	• Purchased electricity	• NA
• Installation of energy-efficient devices	• Dalin Tzu Chi Hospital, Taiwan, China[20]	• Purchased electricity	• Yes
Single-use item elimination			
• Reusable tableware policies and campaign	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[25]	• Single-use plastic bags	• Yes
	• Dalin Tzu Chi Hospital, Taiwan, China[20]	• Single-use straws	• NA
• Digitalization of medical records	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[26]	• Paper sheets	• NA
• PPE reprocessing	• Mary Johnston Hospital, Philippines[27]	• Single-use PPE	• NA
Sustainable waste management			
• General waste recycling	• Ibnu Sina Hospital of Gresik, Indonesia[28]	• Waste disposal	• NA
	• Sri Sathya Sai Institute of Higher Medical Sciences, India[29]	• Waste disposal	• NA
	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[26,30] • Dalin Tzu Chi Hospital, Taiwan, China[31]	• Waste disposal	• NA
• Biodegradable waste composting	• Ibnu Sina Hospital of Gresik, Indonesia[28]	• Waste disposal	• NA
• Chemical container waste recycling	• Ibnu Sina Hospital of Gresik, Indonesia[28]	• On-site waste incineration • Incineration fuel	• NA • Yes
• Xylene waste recycling	• Royal Hospital, Oman[31]	• Xylene waste disposal	• NA
• Waste reduction	• Dalin Tzu Chi Hospital, Taiwan, China[32]	• Waste generation	• NA
Water conservation			
• Wastewater recycling	• St. Paul's Hospital of Iloilo, Philippines[33]	• Purchased water	• NA
	• Dalin Tzu Chi Hospital, Taiwan, China[34]	• Purchased water	• NA
• Rainwater harvesting	• St. Paul's Hospital of Iloilo, Philippines[33]	• Purchased water	• NA
• Reusing rejected water from the reverse osmosis machine	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[35]	• Purchased water	• NA
• Water-efficient devices	• Buddhist Tzu-Chi Dialysis Centre, Malaysia[35]	• Purchased water	• NA
Sustainable transportation			
• Cycling promotion	• St. Paul's Hospital of Iloilo, Philippines[36]	• Not specific (car usage substitution with bicycle usage)	• Yes

GHG: greenhouse gas; LED: light-emitting diode; NA: not available (environmental footprint reduction is not reported as GHG equivalent); PPE: personal protective equipment.

using water-resistant microfibres, which could be reprocessed.[27]

Sustainable waste management

The identified sustainable waste management initiatives were grouped according to the types of waste generated, reflecting the breadth of waste streams and underscoring the importance of segregating waste streams arising from the health-care sector. Ibnu Sina Hospital's case study (Indonesia) described the introduction of a "waste bank" system, which enabled staff to collect and deposit general recyclable waste in exchange for cash savings.[28] Additionally, the hospital adopted an aerobic composting scheme for biodegradable waste (e.g. yard waste) and collaborated with local waste enterprises to manage food waste and to recycle chemical containers.[28] Centralized waste segregation bins were also part of a scheme to manage general waste that was implemented at the Sri Sathya Sai Medical Institute in India.[29] Malaysia's Buddhist Tzu-Chi Dialysis Centre adopted a slightly different approach that involved partnering with volunteers to collect recyclables and to repurpose used cooking oil for soap production.[26,30] Two case studies mentioned initiatives to tackle specific waste streams. The Royal Hospital in Oman invested in a licensed xylene recycler to reduce xylene disposal in its laboratories.[31] Dalin Tzu Chi Hospital in Taiwan, China installed haemodialysis machines that minimized dialysis fluid usage during treatment, thereby reducing haemodialysis-related medical waste.[32] The hospital also implemented a recycling programme, involving volunteers and staff, as part of a wider effort towards sustainability through the adoption of integrated waste management policies.[32]

Water conservation

Efforts to conserve water within the health-care sector typically involved reusing wastewater for designated purposes or minimizing water consumption through the adoption of water-efficient devices. A case study from St. Paul's Hospital in Iloilo, Philippines, described the implementation of an advanced water treatment system that purifies and recycles wastewater for toilet flushing operations through specialized aeration technology.[33] The hospital also uses harvested rainwater for washing laundry and flushing toilets.[33] Water conservation efforts at the Dalin Tzu Chi Hospital in Taiwan, China involved outsourcing wastewater recycling and purchasing the recycled water for toilet flushing and landscaping.[34]

The case study from the Buddhist Tzu-Chi Dialysis Centre in Malaysia showcased an effective strategy for reusing rejected water from haemodialysis reverse osmosis machines for toilet flushing, building premises cleaning and plant watering.[35] To further enhance water conservation efforts, the Centre installed flow-restrictor faucets and dual-flush toilets, minimizing overall water consumption.[35]

Sustainable transportation

Activities designed to promote low-carbon alternatives for staff commuting were reported in one study. In St. Paul's Hospital in Iloilo, Philippines, the establishment of an employee cycling club resulted in 120 employees commuting by bicycle.[36]

DISCUSSION

Our review of case studies and reports extracted from HCWH's databases highlights the value of the grey literature as a source of context-specific information about the effectiveness of decarbonization initiatives in Asia. Failure to adequately reflect grey literature evidence in published, peer-reviewed systematic reviews potentially limits the transfer of knowledge and the wider adoption of good practices across the health-care sector. Our narrative review was disproportionately composed of studies from health-care facilities in India and Taiwan, China. Both settings have introduced policy frameworks aimed at promoting sustainable health care – India through the National Centre for Disease Control and the 2019 National Programme for Climate Change and Human Health,[37] and Taiwan, China through the establishment of the Health Promoting Hospitals and Health Services Task Force in 2010 and the incorporation of low-carbon indicators into hospital accreditation in 2017.[38] Nonetheless, their prominence in the literature may be more indicative of facility level rather than of unequivocal regional leadership in decarbonization.

The first-stage review (53 studies) revealed a dominance of energy and waste initiatives in decarbonization efforts. The second-stage review (18 studies) identified similar biases, with reports of GHG emissions reduction equivalents coming almost exclusively from measures targeting purchased electricity. This is likely a reflection of the relative ease of measuring energy consumption under Scope 1 (direct emissions) and Scope 2 (energy purchasing), compared to Scope

3, which involves indirect supply chain and procurement emissions.[39] Currently, both energy and waste initiatives offer more accessible technological solutions and measurable outcomes, but the focus on readily achievable measures may divert attention from targeting indirect emissions from the health sector, which are both more challenging and more high-emission. Indirect emissions include those from the supply chain and clinical practice, and require measures to transition towards low-carbon products and clinical supplies, and to reduce unnecessary prescriptions and testing.[6,9] The reporting bias we observed is consistent with previous studies, which have highlighted the difficulties in implementing supply chain and clinical practice interventions due to the dependency of health-care facilities on external suppliers for decarbonizing their products and services, over which they have limited control. Lack of awareness among health-care organizations regarding GHG emissions scopes, and the important contribution of supply chains, is likely another reason for the bias,[40,41] one that is perpetuated by the limited availability of GHG emissions measurement methods and emission factors for clinical and pharmaceutical products through life cycle assessment.[10,41]

Among the subset of studies included in the thematic review that reported renewable energy initiatives, all involved the installation of PV panels. The experience of one hospital – which opted for a leasing model – highlights the complex interplay of opportunities and challenges in the renewable energy arena. While leasing models effectively address initial cost barriers, they may create long-term dependency on external providers, which could limit facilities' autonomy and financial flexibility. While government subsidies and leasing schemes for renewable energy can facilitate decarbonization of the health sector, without broader structural changes in health-care financing, such schemes may not always provide the most sustainable solution in the longer term.[42] Under these models, it is essential to implement risk mitigation strategies to safeguard energy supply for health services under all eventualities, such as fluctuations in governmental funding, contract disputes, or if an energy company goes bankrupt.[42] Energy efficiency initiatives identified in this study also emphasized the importance of systemic planning and infrastructure upgrades, as well as energy auditing for establishing baselines and performance monitoring.[43] The effectiveness of energy monitoring systems emerged as an important factor in successful implementation, as such systems provide essential data for impact assessment and policy recommendations.[44]

Reviewed single-use item elimination initiatives showed promising results, introducing policy-enabled reusable alternatives that maintained safety standards. Electronic health records demonstrated multiple benefits beyond paper reduction, including operational efficiency and enhanced patient safety.[45] The COVID-19 pandemic highlighted the potential of reusable PPE, offering durability and cost savings over disposable options.[46] Waste management successes largely depended on good waste segregation, tailored to the specific characteristics of different types of waste.[47] As demonstrated by several included case studies, implementation of recycling initiatives can be facilitated by collaboration with external communities,[48] including volunteers and local waste management organizations.

The water conservation theme suggested that feasibility is dependent on water source, with harvested rainwater and dialysis reject water showing potential for safe reuse.[49] Recycled water, however, is restricted to non-human contact applications such as toilet flushing and plant watering. The one transportation initiative, which involved a cycling club, suggested the benefits of employing social promotion as a tool for encouraging positive behavioural changes (in this case, embedding a culture of cycling to work as an alternative to driving). These positive changes were attributed to heightened awareness among participants of health and environmental benefits promoted by fellow club members.[50]

This study also found that most studies that included GHG emission reduction equivalents did not report the GHG conversion methods they used, affecting the comparability of measurable outcomes.[51] This gap is significant, as it increases the complexity of measuring health-care GHG emissions within the sustainability agendas. Therefore, it is suggested that more attention be given to facilitating health-care facilities in reporting their environmental footprint reduction outcomes in GHG emissions. Beyond this, and as there is currently no standardized method for measuring GHG emissions specific to the health-care sector,[7] we recommend that WHO establish standardized technical guidelines for this purpose. In addition to covering data collection protocols and emission factors, these guidelines should emphasize Scope 3 emissions and be designed for country-specific

adoption by health ministries. This would facilitate benchmarking and allow progress to be tracked through health-care accreditation and quality assurance systems.[7]

Limitations

This review is based on case studies included in two databases (GGHH and HCCLI), and thus may have overlooked studies held in other similar databases. Moreover, as these databases document voluntarily submitted case studies, they may lean towards highlighting success stories. Further selection bias may have been introduced by the exclusion of 35 eligible case studies from the thematic analysis; these could not be included due to time constraints in obtaining consent from corresponding health-care facilities. Their exclusion may have led to over-representation of health-care facilities with higher readiness for decarbonization initiatives and underrepresentation of facilities facing greater challenges. These biases may limit the validity and generalizability of the narrative review findings.

Conclusion

Decarbonization initiatives in Asian health-care facilities, as documented in the GGHH and HCCLI databases, demonstrate both progress and challenges that require strategic solutions. The dominance of energy and waste activities among the reviewed case studies shows a tendency to prioritize areas with feasible technological solutions and more readily measurable outcomes, while overlooking the harder, high-emission areas such as supply chain and clinical practice. Reporting of converted GHG emissions was largely limited to purchased electricity reduction, symptomatic of a lack of standardized measurement methodologies for the health-care sector, which currently precludes meaningful comparisons and progress towards sector-wide decarbonization. Without standardized measurement and a deliberate expansion beyond energy and waste, Asian health-care decarbonization risks focusing on lower-impact changes while higher-impact actions remain insufficiently addressed. Future initiatives should strike a balance between easily achievable goals and more challenging systemic changes, while ensuring robust reporting standards across all decarbonization efforts.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

This study did not require ethical approval, as it involved the review of secondary data from case studies.

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