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Original Article

Strategies and Actions to Achieve a Climate-Adaptive Hospital: A Qualitative Study

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ABSTRACT

Background: Climate change increasingly threatens the continuity, quality, and resilience of hospital services by disrupting healthcare delivery and increasing the demand for climate-sensitive care. Hospitals therefore require integrated mitigation and adaptation strategies to reduce their environmental impact while strengthening resilience to climate-related hazards. This study aimed to explore experts' perspectives and experiences regarding strategies and actions for developing climate-adaptive hospitals in Iran.

Methods: A qualitative study using conventional content analysis was conducted between February and May 2021. Purposive sampling with maximum variation was used to recruit 17 experts from diverse disciplines, including health service managers, physicians, nurses, disaster and emergency specialists, environmental health professionals, and hospital construction experts. Data were collected through semi-structured interviews, each lasting approximately 45–90 minutes, until data saturation was achieved and were analyzed inductively using MAXQDA version 11. Trustworthiness was established according to Guba and Lincoln's criteria.

Results: Two overarching categories emerged: climate adaptation and climate mitigation. Climate adaptation comprised technology, financial affairs, monitoring, assessment and evaluation, management and leadership, and hospital buildings. Climate mitigation included water, wastewater, waste, energy and chemical management, transportation, nutrition and food management, implementation of emission-reduction policies, and sustainable models of care. Together, these categories provide a comprehensive framework for improving hospital resilience while reducing environmental impacts.

Conclusion: Developing climate-adaptive hospitals requires the integrated implementation of both adaptation and mitigation strategies. The findings provide context-specific evidence to support hospital managers and policymakers in enhancing resilience, reducing greenhouse gas emissions, improving environmental sustainability, and ensuring continuity of healthcare services under climate change.

Keywords: Hospital; Climate Change; Global Warming; Qualitative Research

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Introduction

Climate change is a major challenge in the 21st century, and the public health sector has suffered the most; in the meantime, it has left detrimental impacts on humans and derails sustainable development. Researchers warn that if the present situation continues, the globe will be overwhelmed by the negative effects of climate change, such as heat waves, floods, storms, and droughts [1, 2]. Some climate-related changes, such as increasing temperatures, shifting rainfall patterns, and rising sea levels, have substantially unfolded during the previous century, according to scientific data, and will continue to do so [3, 4]. According to reports by the World Health Organization, climate change is expected to cause approximately 250,000 additional deaths annually from malnutrition, malaria, diarrhea, and heat stress between 2030 and 2050 [5]. The direct costs of climate-related damage to the health sector, excluding impacts on water, sanitation, and agriculture, are estimated to reach USD 2–4 billion per year by 2030 [5, 6). The health sector not only experiences the impacts of climate change but also contributes to greenhouse gas emissions, highlighting the urgent need for adaptation within healthcare facilities [7, 8]. Globally, the healthcare sector is estimated to account for approximately 4.4% of net greenhouse gas emissions, although this proportion varies across countries and healthcare systems [7-12]. For example, the healthcare sector contributes approximately 7% of Australia's national greenhouse gas emissions and nearly 10% of those in the United States [10, 11]. Reliable estimates for many low- and middle-income countries remain limited [10-12]. The environmental impacts of healthcare extend beyond greenhouse gas emissions and include air pollution, water contamination, and increased pressure on natural resources [8, 9-12]. Hospitals consume substantially more energy than typical administrative buildings because of their continuous and resource-intensive operations [8, 12]. Consequently, hospitals play a dual role in climate change by contributing to emissions while simultaneously responding to the increasing health consequences of climate-related disasters [9, 13–15].

As critical centers of the health system, hospitals play a crucial role in mitigating the impacts of climate change as they treat the injured and patients suffering from climate-sensitive diseases [3]. Climate change, as well as the increased risk of acquiring climate-sensitive illnesses, endangers the quality and continuity of medical treatment. Hospitals' climate actions, such as wise energy usage, water conservation, waste reduction, and improving green spaces, are crucial in combating climate change [4]. According to the Paris Agreement on Climate Change (COP21), all sectors, especially the health sector, must reduce their impact on climate change through a focus on emissions of greenhouse gases. This requires substantial motivation and implementation of more radical measures to mitigate the environmental impact through providing net-zero health-care services. Also, after COP27, many countries have signed up to the WHO agreement to develop climate-resilient and sustainable hospitals, yet there are few examples of this practically being done in the real world [5, 6].

Various guidelines were developed by organizations around the world to meet intelligent health care systems by saving resources, increasing operational efficiency, and reducing carbon emissions. These organizations include the World Health Organization, the World Bank, the Health Care System Without Harm, the Pan American Health Organization (PAHO), the U.S. Green Building Council, the Green Building Council of Australia, Building Research Establishment's Environmental Assessment Method or BREEAM in the UK as well as the Green Building Index in Malaysia being implemented in many other countries. While developed nations are advancing toward mandatory "net-zero healthcare" and "green hospitals," implementation in many developing countries remains limited. Iran is recognized as a climate-vulnerable hotspot, facing severe water scarcity, intensified heatwaves, and pervasive dust storms. Despite this acute exposure, climate resilience remains a peripheral concern within national health sector planning. A 2021 WHO survey revealed that Iran, like many developing nations, lacked a comprehensive national plan for climate-resilient and sustainable health systems, highlighting a critical policy gap that exacerbates systemic vulnerability [7-14]. Despite the growing international emphasis on climate-resilient and environmentally sustainable healthcare systems, evidence on context-specific strategies for climate-adaptive hospitals in low- and middle-income countries remains limited. In Iran, where health facilities face increasing climate-related risks, comprehensive evidence to inform hospital-level adaptation and mitigation planning is lacking. Addressing this knowledge gap is essential for developing evidence-informed policies and strengthening health system resilience. Therefore, this study aimed to explore experts' perspectives and experiences regarding the strategies and actions required to develop climate-adaptive hospitals in Iran.

Methods

Study Design

This qualitative study employed conventional content analysis to explore experts' perspectives on hospital preparedness and countermeasures for climate change. Content analysis was used to systematically derive concepts and categories from textual data [15, 16]. This approach assumes that meaning is constructed through

interaction between the researcher and participants and is influenced by context and interpretation.

Sampling and Setting

Purposive sampling with maximum variation was used to recruit experts in climate change and health from different regions of Iran. Participants included civil engineers, mechanical and installation engineers, architects with experience in hospital construction, health service managers, disaster and emergency specialists, environmental health experts, physicians, nurses, stakeholders, and officials from hospital planning divisions. Inclusion criteria were: [1] relevant scientific or professional knowledge (e.g., publications, academic work, or theses related to the topic), [2] professional experience in hospital-related or climate-related fields, [3] ability to articulate experiences and perspectives, and [4] willingness and sufficient time to participate in the study.

Data Collection

Data were collected through semi-structured, face-to-face interviews conducted by the first author using an interview guide with open-ended questions aligned with the study objectives. Probing questions were used to deepen exploration of participants' perspectives, such as: "What measures are currently implemented in hospitals to address climate change?" "How do you evaluate hospital preparedness for climate-related challenges?" "What components should be strengthened in hospitals for climate adaptation?" Additional probes explored preparedness for specific climate-related hazards, including extreme heat, water scarcity, flooding, air pollution, and environmental emergencies, as appropriate to participants' expertise.Written informed consent was obtained prior to participation. Interviews were conducted in Persian, the participants' native language, at their workplaces or at locations of their preference. Nine interviews were conducted in person and eight interviews were conducted online due to COVID-19 restrictions. Interview transcripts were translated into English by the first author and reviewed by a bilingual researcher to ensure conceptual accuracy. Data collection continued until saturation was reached, defined as the point at which no new concepts emerged from subsequent interviews. Data saturation was independently assessed by the first and corresponding authors through concurrent data collection and analysis. Interviews were conducted between February 2021 and May 2021, with durations ranging from 45 to 90 minutes (average 60 minutes).

Data Analysis

All interviews were transcribed verbatim and analyzed using inductive qualitative content analysis. Data analysis began concurrently with data collection. MAXQDA software (version 11) was used for data management.Initial codes were generated through repeated reading of transcripts and identification of semantic units. Codes were continuously compared using the constant comparative method. Through iterative analysis, similar codes were merged, redundant codes were removed, and synonymous codes were integrated. Codes were organized into subcategories and broader categories based on internal homogeneity and external heterogeneity. Finally, overarching themes were extracted to capture the main conceptual patterns in the data. To ensure analytical rigor, coding and categorization were independently reviewed by two members of the research team, and discrepancies were resolved through discussion and consensus [17, 18].

Rigor and Trustworthiness

Trustworthiness was ensured using the criteria of credibility, dependability, confirmability, and transferability proposed by Guba and Lincoln [16].

Credibility was strengthened through prolonged engagement with the research process from study design to data collection, analysis, and interpretation. The research team had extensive experience in hospital settings and climate change-related research. Member checking was performed by returning preliminary findings to selected participants for verification. Peer debriefing and peer review were also conducted throughout the analysis process.

Dependability was ensured through systematic documentation of all research procedures and external review of the analytical process by qualitative research experts.

Confirmability was achieved through maintaining a transparent audit trail, including interview transcripts, coding decisions, category development, and theme extraction, ensuring that findings were grounded in the data and minimizing researcher bias.

Transferability was supported through maximum variation sampling across professional roles, geographic regions, age, and experience levels. Although statistical generalizability is not the goal of qualitative research, thick description enhances applicability to similar contexts.

Ethical Considerations

Ethical approval for this study was obtained from the Ethics Committee of Tehran University of Medical Sciences (Approval No. IR.TUMS.VCR.REC.1398.911) prior to data collection. All participants received detailed information regarding the study objectives, interview procedures, voluntary participation, confidentiality, and their right to withdraw from the study at any stage without any consequences. Written informed consent was obtained before each interview, including permission for audio recording. To ensure confidentiality, all interviews were anonymized, identifying information was removed during transcription, and the data were securely stored

with access restricted to the research team.

Results

Demographic characteristics of participants:

The average age of participants was 39.9 [34, 49], with 12 males and five females. Also, five participants held a B.A. degree, 3 had an M.A., and the others were doctoral and PhD. The characteristics of the participants are given in Table 1.

Categories

The following two Categories emerged out of the analysis of experts' views and experiences: "climate adaptation in hospitals" and "climate mitigation in hospitals" as summarized in Table 2.

Discussion

Climate change and its impacts increase demands for health care and create new challenges for hospitals; to deal with these challenges, hospitals require strategies to deal with climate change. According to the findings, one of the main priorities of hospital actions is to limit their contribution to the climate change process, especially by reducing their emissions. The first step for hospitals is to understand their share in producing greenhouse gases and the places the gases are coming from. Nowadays, there are many tools for measuring greenhouse gas emissions, from general calculators to consultants' specific hospital audits. The US Environmental Protection Agency estimates that a large amount of healthcare energy is reducible. Hospitals should use strategies to mitigate the impacts of climate change to decelerate the warming process. These strategies include the use of low-carbon health measures such as gathering and storing rainwater and using it to irrigate hospital greenery, policies aimed at using renewable energy, actions on maximizing energy efficiency [19] and minimizing waste, strengthening hospital facilities [20], providing cycling or walking paths for staff and easy access to public transportation [21], and designing hospital buildings to use most light and natural ventilation. The healthcare sector is required to consider the impacts of climate change and take appropriate measures to decelerate the process through rapid implementation of carbon reduction initiatives that also help enforce healthcare standards [22]. However, at this critical time, reducing emissions is no longer an option. Hospitals can no longer ignore climate change, as they should focus on reducing global warming through rapid implementation of carbon-reduction measures. This study emphasizes the importance of environmentally sustainable investment to help reduce greenhouse gas emissions, improve the environment, and improve human health. In the future, efforts should be directed toward providing hospital-compliant tools for implementing the best programs, and measures, and adding a scoring component so that hospital managers can track the progress of measures [23].

Adaptation is the second main strategy endorsed in the Paris Agreement. It is a key issue in dealing with the impacts of the climate change, which includes predictions and preparedness against climate change impacts [24]. The increase in Weather-related extreme events (such as heat waves, droughts, and floods) and the increase in the prevalence of infectious diseases transmitted by water, food, carriers, and rodents, which are attributed to climate change, lead to considerable risks for human health and medical centers. Because of the uncertainty about the extent, speed, and nature of climate change, there is an urgent need to create adaptive capacity and resilience in hospitals against climate change. Hospital resilience is a new concept and is defined as "the ability of hospitals to resist, absorb and respond to stresses of disasters, along with maintaining their therapeutic functions and returning to

Table 1: Demographic characteristics of the study participants

Participant no.	Age (years)	Gender	Educational level	Educational Discipline
P1	38	Female	PhD.	Health in Emergencies and Disasters
P2	35	Female	PhD.	Health in Emergencies and Disasters
P3	39	Female	PhD.	Health in Emergencies and Disasters
P4	37	Male	PhD.	Health in Emergencies and Disasters
P5	36	Male	PhD.	Health in Emergencies and Disasters
P6	40	Male	PhD.	Health in Emergencies and Disasters
P7	40	Female	Bachelor's degree	Nurse
P8	37	Male	M.D.	Medical Doctor
P9	34	Female	M.D.	Medical Doctor
P10	39	Male	Bachelor's degree	Civil Engineer
P11	37	Male	Bachelor's degree	Civil Engineer
P12	49	Male	Bachelor's degree	Architectural Engineer
P13	42	Male	Master's degree	Mechanical Engineer
P14	44	Male	Bachelor's degree	Environmental health engineer
P15	46	Male	Master's degree	Environmental health engineer
P16	44	Male	Master's degree	Health services management
P17	42	Male	PhD.	Health services management

Table 2: Main Categories provided by experts

Category	Subcategory	Concepts	Codes	Samples of Quotations
Mitigation	Water consumption Management	Conserving and saving water resources	Implementation of training programs for personnel and patients Using equipment with new technologies for the maximum amount of saving in water consumption Monitoring consumption and costs Green space management Regular control of pipes and other plumbing to prevent potential leaks	"We could optimize water consumption using stylish faucets in the hospital's restrooms, kitchens, and laundry. Nonetheless, how to prevent water leakage from pipes and heating-cooling systems has been largely missed. This is while we could contain large amounts of water from flowing into the wastewater in hospitals at very low costs. Not only the technical matters but also the daily routines of personnel and the conduct of the patients markedly affect water consumption. Personnel shall avoid keeping the faucet open, excessive washing, ..." (p 1) "Many little things are ignored in the hospital that can save huge volumes of water: (for example) wearing own clothes by the patients instead of the hospital gowns. The hospital gowns unnecessarily raise water consumption during washing. Or, we can use no-touch sensor taps in washrooms, as they automatically block water flow during brushing and washing of teeth where patients and/or personnel forget to turn off the tap..." (p 16) "Hospitals are advised to instruct the personnel and patients on how to be liable and sensitive for water usage and remind them of monthly water consumption limits. These are achieved by organizing training programs and courses through installing educational banners in the hospital area to spotlight some key facts (e.g., "Water is Available but Scarce"), as well as posters depicting recent droughts ..." (p 10)
		stormwater management	Using the rainwater collection system	"Some strategies shall be heeded, such as utilizing water-efficiency washing machines in the Central Sterile Room (CSR) (e.g., in operating room and laboratory), using digital radiology equipment as an alternative to film radiography, establishing industrial water-efficient laundry machines, and substituting high-consumption equipment with low-consumption models ..." (p 14). "We could reduce water consumption by cultivating drought-tolerant, ecologically adaptive plants and flowers which require low water for growth and development. Again, strategies such as utilizing drip irrigation for landscapes instead of traditional irrigation and using colored pebbles instead grass are quite helpful..." (p 15) "...Using roofs and other space to store rainwater for use in the irrigation of landscapes or washing floors in the hospital building diminish water consumption ..." (p 8)
	Wastewater management	Sewage separation, collection, and occupation	Separation of wastewater from different departments of the hospital Physical separation of hospital wastewater	"Collecting and disposing of hospital wastewater shall follow the guidelines of the World Health Organization (WHO), the National Water and Wastewater Organization (NWWO), and the Ministry of Health so as to ensure the suitable treatment and prevention of environmental pollution before entering the municipal wastewater ..." (p 15)
		Purification, disinfection, and filtration of hospital wastewater	Wastewater recycling at the hospital site before entering the municipal sewage system Using efficient filters to remove pollution	"The hospital's wastewater might be potentially combined with an overflow and thus contaminate the environment. Thus, it is necessary to have pre-designed plans for collecting and separating the hospital's wastewater…" (p 5) "Pathogens found in hospital wastewater are deemed a significant risk for the health of society. Just imagine they are drug-resistant. Then, how much do you feel they will exaggerate the problem? This is why hospitals should have specific treatment plants. Hospitals have various solutions in hand for wastewater treatment. These are anaerobic or aerobic treatments such as membrane bioreactor (MBR) and moving bed biofilm reactor (MBBR) technologies, which differ from one hospital to another ..." (p 14)
		Reuse and recovery of hospital wastewater	Using efficient wastewater conversion and recycling technologies	"Hospital managers can sign an agreement with the Ministry of Energy (MOE) or private firms in order to use novel technologies for treating the wastewater and reusing it in other wards ..." (p 7) "Given the high volume of water consumed in the dialysis ward, the wastewater produced could be treated by novel tools and technologies via reverse osmosis, and then used for irrigation in the hospital area ..." (p 15)
	Waste Management	Waste reduction	Implementation of the "Zero Waste Production" policy in the hospital	"…Wastage should be appropriately separated and recycled. Hospitals should be equipped with waste-incineration facilities, apply alternative machineries, and control some of their waste. This helps them prevent

Continued Table 2

Category	Subcategory	Concepts	Codes	Samples of Quotations
			Frequent inspections of reducing the waste production	dumping their toxic and infectious waste into the environment. Waste-incineration systems are equipped with filters that absorb polluting gases and prevent their emissions…" (p 13)
		Waste collection	Proper storage Proper segregation of waste Proper transportation of waste	"…Training personnel in relation to waste and its management can be very helpful. This helps every individual to reduce waste at hospitals. These training, either at clinical wards where physicians perform clinical procedures or at some other units where infectious waste need to be dumped are necessary…" (p 17)
		Recycling	Contracting with companies to turn waste into fertilizer or compost instead of incineration	"Hospital waste should be collected at an appropriate place, and sufficient training should be provided to staffs as to how to properly collect, separate and eliminate the waste…" (p 5)
		Waste disposal	Training and increasing the awareness of personnel Waste disposal according to the national regulations of the countries and the recommendations of the World Health Organization and the CDC	
		Reducing energy consumption	Training programs for personnel on modifying the personnel's pattern of consumption Using low-consumption equipment with high efficiency (class A)	"…The use of clean and renewable energies such as solar panels on rooftops and wind energies should help hospitals provide their own energy. Although investment in this sector may incur higher costs for hospitals, it can reduce energy consumption and help hospitals increase their efficiency in the long term…" (p 13)
		Energy audit	Frequent inspections of energy consumption in the hospital	"…Knowledge of regional climates and use of clean and renewable energies in those regions is very critical. For example, in areas with high wind potentials, the installation of wind turbines for power production and reducing fossil fuel consumption is effective…" (p 4)
		Use of alternative sources of energy supply	Use of renewable energy sources in the hospital	Another item is the reduction of dead spaces at hospitals when developing a model for energy reduction consumption.
			Upgrading lighting systems	"…For me, eliminating dead spaces at hospitals to reduce energy such as power and heating consumption is very helpful; however, this requires replacing ventilation and using optimal energy consumption at various spaces…" (p 11)
			Improving the thermal condition of the building	One more issue raised by the interviews was lighting in hospitals.
	Energy Management		Improvement of the insulation condition of the building	"…Given their geographical position, hospitals can enjoy the natural light. Solar power can be utilized in sites where artificial lighting is going to be used. Also, lamps with sensors should be used so that they automatically switch off when people forget to do so…" (p 12)
			Improvement of the ventilation of the hospital	"…Hospital lighting systems should be intelligent in order to increase or decrease lighting in accordance with the requirement of the environment; this will certainly help optimize energy consumption. Automatic lamps should replace manual lamps in hospitals, i.e., lamps with sensors are preferred which minimize power consumption, also…" (p 11)
		Energy Efficiency		"…Installing hospitals' windows with double-glazed glasses, insulating the buildings, launching ventilation systems, replacing the old equipment with new one and utilizing higher-efficiency facilities as well as repair and maintenance could reduce energy consumption greatly…" (p 13)
			Refrigerant Management	"…The equipment used at hospitals, such as refrigerators, equipment inside the laboratories and electrical tools and computers should consume less energy and have higher efficiency rates…" (p 13)
				"…Hospitals should be developed in a way to manage energy consumption. Older equipment needs to be replaced with modern machinery to reduce energy consumption…" (p 3)
	Chemicals Management	Implementation of the principles of improving the	Use of non-toxic materials Management of hospital gases	"... We should employ novel anesthesia procedures in hospitals, e.g., using xenon gas that is more environmentally safe than other anesthetic gases; or use technologies such as "blue-zone" that are developed to absorb and purify halogenated anesthetic gases. Again, we can train

Continued Table 2

Category	Subcategory	Concepts	Codes	Samples of Quotations
		management of chemicals in the hospital	Reducing spraying in the hospital to control AFA	anesthesiologists and personnel working in the operating room on how to correctly use anesthetics, especially nitrous oxide (N2O) …" (p 9)
			Management of low-risk disinfectants in the hospital	"... Buildings of the hospital should be constructed of pest-resistant materials that exclude pests from entering the building. They further should be seamless and have no empty spaces. Additionally, the pests should be controlled by periodical spraying of boric acid. Ultimately, installing physical barriers (e.g., nets) in the entrance (i.e., doors and windows) allows for less application of pesticides…" (p 14)
			Reducing environmental pollutants in the hospital	
			Management of laboratory materials	"... Hospitals should prepare materials safety data sheet (MSDS) and deliver them to the personnel who work with these materials. It is crucial to train the personnel in advance on how to work with (and dispose of) these chemicals. The hospital officers should purchase materials that possess the least environmental hazards and avoid purchasing higher than the hospital's actual requirement. Likewise, all personnel should learn how to work with personal protective equipment (PPEs) to avoid potential events …" (p 15)
			Improving the management of drugs and pharmaceuticals	"…Conventional hand-held disinfectant sprayers should be replaced with automatic systems to allow using less volume of disinfectants. Utilizing safer agents than those containing glutaraldehyde and ethylene oxide and/or using triclosan- and triclocarban-free soaps could largely prevent environmental contamination…" (p 14)
				"…In order to reduce the environmental impact, hospitals shall develop guidelines for ranking medications by their consequences and deliver them to physicians for the right prescription of drugs. It is likewise pivotal to train physicians on how to avoid excessive dispensing of drugs and instruct patients on 1) how to consume medicines during hospitalization and after that, 2) how to dispose of medicines at home, and 3) why this is necessary to avoid disposing of medicines into the urban wastewater network to prevent environmental pollution…" (p 8)
				"... Pharmacies can diminish drug waste via using near-expiry drugs or distributing them among the other wards. They also can sign contracts with manufacturers to deliver expired drugs to them and obtain fresh drugs from authentic companies ..." (p 9)
	Transportation	Optimal management of personnel	Personnel training on reducing fossil fuel consumption	"... If sought at reducing the consumption of fossil fuels, the personnel shall be motivated toward walking and using bikes. Although it comes with multiple benefits, the use of bikes requires proper infrastructure, e.g., paths and parking lots for personnel and other users. Again, training personnel on using public transportation is a useful solution ..." (p 16)
			Creating financial incentives for personnel to reduce the consumption of fossil fuels	"... Expanding the culture of car sharing among personnel and with other organizations allows for minimizing the trips. Suppose everyone wants to use their private car to get to the hospital; then how much fossil fuel do they consume? The next solution is personnel's easy access to public transportation or a hybrid vehicle instead of private cars. Note that the existence of large parking lots in the hospital area inspires personnel and patients to use private cars instead of public transportation ..." (p 17)
			Policy of reducing unnecessary travel	
		Management of vehicles in the hospital	Optimization of vehicles in the hospital	"... Providing the transportation department personnel with effective ways to reduce fuel consumption and not use of private cars, setting constraints on the use of parking lots except for urgent situations, and inspiring personnel by giving low-interest loans for buying bikes and hybrid or electric cars are effective in reducing the consumption of fossil fuels ..." (p 4)
				"... Using ambulances and vehicles operated with renewable fuels, e.g., biodiesel, is highly efficacious in lowering the rate of environmental pollution. Likewise, the air quality index (AQI) is enhanced by advanced monitoring systems and tools (e.g., tracking the movement of each vehicle in a fleet), monitoring the volume of fuel burned, identifying the source(s) of air pollution in exhausted and heavy-duty cars, and providing regular services ..." (p 6)
				"... Some hospitals even use vehicles to move patients between different wards of the hospital. In line with this, engine-less cars improve productivity and preserve fuel …" (p 1)
	Nutrition and food management	Promotion of sustainable and	Changing the pattern of food consumption in the hospital	"... Hospital canteens and refreshment stands should be seen as a site for publishing information. Regular training on healthy and organic

Continued Table 2

Category	Subcategory	Concepts	Codes	Samples of Quotations
		low-carbon food		food habits is an effective way to eliminate harmful substances from the diet of personnel, patients, and their comrades ...” (p 7).
				“... In hospitals, using less meat on menus is highly efficient in lowering the emission of GHGs …” (p 5)
				“... Vendors are better to buy food from local people to diminish transportation and support their job as a source of earnings. Note that food preparation shall produce minimized waste and require less packaging for distribution...” (p 17)
			Do not advertise unhealthy foods	“...Training personnel working in the Department of Dietetics & Nutrition and kitchen about water and food-borne diseases and adequate depot of food ingredients for supplying personnel and patients daily are critical for the enhanced round-the-clock hospital performance...” (p 14)
				“…Food distribution should need fewer packaging and produce little food waste. Also, as regards primary food sources at hospitals, taking less meat in hospital menus to reduce greenhouse gas emissions will be highly effective...” (p 1)
			Longevity and efficiency	“...The hospital's purchasing managers shall place domestic and local products in high priority. Not only this will support the local economy but furthermore minimize transportation and handling ...” (p 2)
			Changing the purchase pattern of products	“...An important factor that the hospital's purchasing manager(s) should consider is minimizing the production of waste. For instance, we could reduce medical waste by restricting the purchase of unnecessary items and preventing the products from expiration. Simply put, we could use sterile products that are already unpackaged or even expired products for non-sterile applications…” (p 5)
			Prevention of contamination in hospital purchases	
	Implementation policies and rules on reducing emissions	Environmental Preferable Purchasing		“...Hospital purchasing managers could make reasonable purchases to reduce adverse environmental effects. This includes assessing the environmental impact of the purchased goods during their use, i.e., from production to disposal. Nonetheless, it is pretty challenging, as supply chains are typically quite long-drawn-out and multi-faceted…” (p 17)
			Follow ethical rules from production to final packaging and disposal	“... The purchasing managers shall consider many factors when substituting and purchasing new products. For instance, even buying and replacing paper required in offices may bring some unforeseen concerns for printers. The use of endurable materials includes reflecting safety considerations, the life of the product, recyclability, and the product reuse…” (p 16)
			Training for doctors and personnel	“…The dispensation of medications, X-ray imaging, and a patient referral to a specialist for surgery all come with environmental impacts. Hence, we could help to reduce carbon emissions and save resources by regularly training physicians to lessen unnecessary care. Again, instructing patients and their comrades through various methods to promote their awareness of the disease and employing self-care techniques to avoid re-hospitalization and enhance health are crucial. Not only do these actions deliver positive health outcomes, but they also bring environmental and financial advantages…” (p 8)
			Educate patients	
	Care models	Sustainable and low-carbon care models	Providing services at home to specific patients in specific weather conditions (such as air pollution, extreme cold and heat)	
			Application of new technologies in the hospital	“…using telemedicine reduces physicians’ commuting to the hospital, and thus reduces fossil fuel consumption …” (p 9)
			Use of Health Information Technology	“…Electronic prescription, HIS, and PACS in hospitals can reduce the need for the uncontrolled use of paper in hospitals….” (p 2)
				“…Using modern technologies to dump wastage and converting it into energy to change time-consuming and energy-intensive processes into shorter and low-consuming processes are very important….” (p 6)
Adaptation	Technology	Utilization and promotion of technology	Application of electronic health (e-Health, telemedicine)	“…One of the advantages of virtual space development, especially during Coronavirus, was educating students via the Internet and on virtual space which led to their decreasing commuting of the hospital…” (p 12)
				“…The hospital can use new technologies to significantly increase its functions. For example, hospital directors can use climate predictions and the probability of rising sensitive patients to increase their capacities proportionate to predicted demands…” (p 14)
	Financial affairs	Allocation of funds for	Financial support and economic incentives	“…To me, any expenditure on countermeasures to deal with climate changes is a kind of investment, with the measures involving scientific

Continued Table 2

Category	Subcategory	Concepts	Codes	Samples of Quotations
		countermeasures	Supervision of financial resources and credits	calls to support research and financial incentives for personnel to remove obstacles on the way of countermeasures. This wide spectrum should be separately taken into account in annular hospital budgets…" (p 17)
		Insurance	Improvement of insurance mechanisms for payment of damages	"…Managers should monitor and regulate the spending of financial credits and budgets allocated in countermeasures, and the level of operation progress in each of the units, as well as reporting on expenditure made…" (p 16)
				"As leading bodies in the area of health, hospitals must have the financial means under emergency conditions. In the hospital budget, an estimate of direct and indirect costs caused by climatic incidents, costs of catastrophe mitigation measures, and hospital insurances should be considered" (p 13)
	Monitoring, assessment, evaluation	Risk assessment	Identifying regional hazards of the hospital Assessing hospital vulnerability to hazards Health database of the area covered in the hospital	"…In this connection, hospital managers should identify hazards in their regions caused by climate changes, and foresee plans for each of the hazards in structural, non-structural, and functional domains. Personnel protection plans against weather hazards, including fires, safe havens for personnel and patient gatherings at the time of incidents, etc. require hospitals to promote their preparation against natural disasters…." (p 5)
				"… The establishment of disease surveillance systems and the reporting of food and water-borne diseases caused by climate changes, infectious disease monitoring, using laboratory networks to discover and control contagious diseases sensitive to climate changes could help promote hospital functions…" (p 3)
		Early warning systems	Syndromic surveillance	"…The establishment of a comprehensive health database for people of a region covered by the hospital, the prevalence rate of cardiac and respiratory diseases, the prevalence rate of renal and dialysis patients, monitoring locally contagious diseases in a region, providing a good response through the Surge Capacity Program in case of the rising number of these patients, and increasing hospital beds and the number of doctors and nurses …" (p 6)
	Management and leadership	Organization	Joining hospitals to the global environmental protection network Active incidents reporting system Monitoring the implementation of hospital accreditation standards and integrating climate measures into it	"…Increasing hospital capacities is made by strengthening incident command systems in hospitals and establishing emergency response programs in hospitals to appropriately respond to climatic disasters…" (p 4)
				"…A commander is entrusted with forming a rapid damage assessment team and meeting hospital needs in climate-related incidents, while hospital preparation should be rapidly increased following an incident…" (p 7)
		Command	Improvement of Incident Command System (ICS) for rapid response in emergency cases Needs assessment Coordination and interaction with cooperating and supporting organizations and institutions	"…Hospitals should ink cooperation memoranda of understanding with other hospitals to supply manpower and equipment under emergencies, and hence apply for their required equipment from relevant suppliers under emergency conditions. Also, hospital officials should communicate and coordinate with NGOs and media to engage local authorities before hazards unfold…" (p 9)
				"…There should be a databank of stored equipment so that it is easily accessed when required. The equipment including an adequate number of individual protection gear should be provided to employees, who should be trained how to use them…" (p 2)
		Logistics management	Supply Chain Management Data management Personnel recall and transfer system Create a hospital equipment database	"…Through appropriate storing and locating, equipment should be provided to deal with disasters…" (p 4)
				"…Managers should improve their preparation by predicting their client' visits and changes made to the services offered to them. They should improve this preparation by supplying necessary resources and equipment, and train their manpower…" (p 3)
		Planning	Disaster planning Develop a specific Emergency Operations Plan (EOP) to deal with climate related disasters Discharge planing for Surge Capacity programs	"…Before climate changes-related incidents, hospitals should provide and rehearse climate change-related incident hazard programs which are specific to each hospital section, and introduce rapid need assessment programs, and emergency response systems…" (p 1)
				"…For example, in arid and desert regions, recently affected by flooding, which already lack a program in hospitals to control flooding and establish an emergency exit plan, there should be programs for the rapid evacuation and exit of personnel and patients, and to determine

Continued Table 2

Category	Subcategory	Concepts	Codes	Samples of Quotations
			Existence of emergency exits to evacuate staff and patients	which structural and non-structural changes should be made for such hazards…" (p 6)
			Training and practice to increase personnel preparedness	"… Before disasters, access paths to hospitals should be made available through helicopter landing sites, ambulance entry paths, ramps, and the establishment of treatment and support units on different floors, while safe havens and secure gathering places should be provided for employees and patients…" (p 5)
		Human resources	Forming a database of hospital staff	
			Management of volunteers	"… I went to a doctors meeting in the hospital and found that the issues of the environment and climate changes were not being discussed. In my opinion, students' syllabus should involve one or two curricular units on health and climate changes and the importance of environmental issues, and also a constant training program should be provided to employees who are now doing their work in hospitals so that they are become more sensitive to this subject…" (p 2)
			Establishing an emergency committee in the hospital	
		Safety promotion	Integration of safety standards with treatment procedures	"…An interesting point is hospital employees' awareness; i.e., how much they know about climate changes, how much training they have received about climatic hazards, and how much they are ready to take up this issue individually and organizationally…"(p 5)
			Optimizing and upgrading the power system	
			Optimizing and upgrading the water and sewage system	"…Concerning human force, the potentialities of volunteers to be employed in hospitals at the time of climatic disasters should be taken into account, and programs should be provided in this connection. Collaboration by Charity Foundations could also increase response to incidents in hospitals…" (p 7)
			Optimizing and upgrading IT and communication systems	
			Optimizing and upgrading the fuel system	"…All hospital infrastructure should be resilient against regional climatic disasters and incidents. Electricity supply systems and emergency electricity generators, water and wastewater monitoring, and their resilience against climatic disasters energy storage and backup systems, hospital's air-conditioning system stability, fuel storage resource safety by the time of disasters, and medical gas system replacement are some of the effective measures in this connection…" (p 3)
		Infrastructure	Optimizing and upgrading heating, cooling, and air conditioning (HVAC) systems	
			Optimizing and upgrading the firefighting system	"…Against climatic hazards, non-structural equipment safety inside hospitals, the establishment of fire extinguishing systems, equipment de-icing systems, and medical gas system safety, as well as alternative resources should be taken into account…" (p 15)
			Optimizing and improving the medical gas system	
			Optimizing and upgrading protection systems	
			Implementation of building codes and design of a green and carbon-free hospital	"…From a land use perspective, hospital spaces, both at design and redesign stages, should involve spaces to meet green hospital standard principles. Specific conditions of each region, such as topography and stable design, should be regarded in hospital facility designs..." (p 11)
		Green Building	Prevention of pollution caused by hospital construction	"…In stable hospital structure design, it is critical to pay attention to reducing thermal island impacts under warm and dry climates, to reduce heat loss in buildings, and to reduce the effects of winds and typhoons in cold climates…" (p 12)
			Design of a resistant structure	
		Building resistance	Continuous monitoring of hospital structures	"…To occupy less space, hospitals should be designed vertically and establish physical communication between the sections on different floors. This issue helps reduce energy consumption because as regards cooling and central heating system if a building is flat-made, it requires a greater amount of energy…" (p 12)
			Choosing the suitable site to reduce the risk of disasters	
	Hospital building		Choosing the suitable site for maximum use of renewable energy	"…In the design process, hospitals should have more green spaces. More green spaces contribute to environmental issues, creating a cooler place in summers and reducing pollution…" (p 11)
		Hospital location		"…Concerning hospital structure stability, such factors as using resistant materials in buildings, structural integrity, and configuration, and using lateral resistance systems, the continued monitoring of structural factors, and structural age should be taken into account…" (p 10)
			Improving hospital access routes to public vehicles	"…Consistent with their geographical locations, hospitals should be designed to be distant from flood paths and rivers, dust centers, industrial places, and warehouses containing dangerous materials. They should be designed to make the best use of solar, wind, thermal, and natural ventilation energies…" (p 12)

the initial state before the occurrence of disasters" [25]. Likewise, hospital resilience is associated with reducing vulnerability to shocks caused by hazards and increasing adaptive capacity. Because of the increase in accidents and disasters due to climate change, it is necessary to make plans to provide a favorable and timely response to treatment needs and provide services to patients within the framework of hospitals that are compatible with the needs and conditions of the time and local climate. Knowing the indicators and characteristics of a resilient and adaptable hospital can provide the grounds for changes in hospital structures with the aim of greater resilience. It should have the capabilities and accepted standards to adapt to the needs of patients and victims of climatic events such as floods, storms, dust, heat waves, extreme cold, epidemics of infectious diseases, and malnutrition. Having a strong emergency management plan that includes measures for prevention, preparedness, response, and recovery after severe weather disasters increases resilience against severe climate change. Response operation plans with an all-hazards approach should be changed and events and hazards of climate change, such as extreme weather events, should be considered within the plans for increasing preparedness. Risk management of climate change requires that medical centers regularly conduct risk assessments to integrate current climate variability and future climate change. In areas that are vulnerable to climate hazards such as floods or storm surges, adaptation efforts to increase building safety and protect critical equipment can increase resilience, as the capacities can increase for preparing for increased numbers of patients and associated pressures.

The use of new technologies also greatly contributes to increasing energy utility. Studies have suggested the telemedicine role and health information to reduce carbon emissions in the health sector [26, 28]. Also, financial resources for reducing emissions should be taken into account in hospital budgets. Personnel insurance is key in transferring incident-caused risks. The use of early warning systems about the impacts of climate change, gathering health data, and estimating them in simulation models are seen as major guidelines [29]. Staff play a key role in creating resilience and stability against climate change impacts. Raising awareness, training, empowerment of, and attention to staff's health and security are key requirements provided in protocols to implement countermeasures [30]. Desirable performance of hospitals during and after the incidents and their continuity to provide services depend on factors such as the stability of hospital structures and non-structural structures [31]. It is also necessary to use modern equipment to respond to emergency needs. In this connection, the existence of backup utility facilities, transportation networks, gas supply systems, and non-structural components such as hospital architecture is highly important. Also, Backup systems need to be installed properly to resist external impacts. Notably, non-structural components generally account for more than 80% of total hospital expenditure [10, 32]. Hospitals should have various water supply resources. Moreover, it is essential to monitor the quality of water for various consumptions. In this connection, it is imperative to install drinking water storage equipment and launch reverse osmosis to supply water and adequate water for health and sanitation. In addition, the sewage systems should be designed in such a way as to prevent any leakages. Thus, to improve hospitals' adaptation, the sewage can be used for unnecessary goals such as horticulture and cooling [33]. There must be warehouses at hospitals to store waste under emergency conditions to prevent infectious waste contamination under such circumstances [34].

Authorities at hospitals need weather data to forecast climate incidents such as heat and cold waves before they unfold. They need databases to provide planning in this connection. For example, they can respond to a rising admission of patients by increasing their workforce. Also, they need to take into account information about beds, alternative care wards, and logistics management to meet clinical care demands. In addition, hospitals should consider mechanisms for volunteer participation and other services at stages prior to disasters. Importantly, resiliency requires several stages before reaching optimum conditions [35, 36]. Concerning information sharing, stakeholders are expected to provide hospitals with regular and systematic reports on interventions to control climate change impacts. Hospital directors are required to attend scientific and international conferences to provide their feedback on this issue.

Zhong et al. (2014) introduced the areas that affect the resilience of hospitals in China. The areas mentioned in this research were structural and non-structural safety, emergency services, overcapacity, command, logistics, hospital personnel, communication systems, and rehabilitation. This research highlights the management aspects of hospitals in structural and non-structural safety during accidents and disasters. Continuity of emergency services was one area in this study, which requires two factors, namely emergency and overcapacity of the hospital. While service continuity should include facility services, employee engagement, and other similar areas. Lack of distinction between non-structural components such as windows and doors with laboratory and medical equipment or electrical facilities and lack of reference to hospital financial support were other weaknesses of this research [37].

Aliabadi et al. (2020) in a systematic review of the resilience of hospitals against disasters, divided it into 3 areas and 27 sub-areas. The main areas were structural, non-structural, and functional resilience. Structural resilience includes all structural elements of the hospital, architectural elements, and the design of spaces and structures for optimal performance,

which are inherently flexible, strong, and compatible with emergency conditions. They pointed out that transportation and communication of the hospital should be designed and predicted before the construction of the hospital to make it easy for patients and medical staff to access the hospital. Infrastructural resilience encompasses non-structural elements that facilitate the function of the hospital. Equipment and services such as electricity, water control, or protection against fire incidents were among the relevant indicators of this section. The protection of electrical installations against disasters was saliently a sub-area of infrastructural resilience. The area of functional resilience included activities for risk management in the hospital, such as risk and vulnerability reduction measures, increased preparedness, response, and post-disaster rehabilitation programs. Considering the importance of repairing and rebuilding structural and utility systems, the cost and priorities of these measures were supposedly financing and recovery in administrative resilience [35].

To encourage the development of smart hospitals, the Pan American Health Organization (PAHO) designed a set of tools including the Hospital Safety Index (HSI), a checklist on environmental protection measures, an appendix on the cost-benefit analysis guide, and a guide to sustainable construction. The Hospital Safety Index is a quick and low-cost diagnostic tool for assessing hospital safety in disasters and provides information on hospital strengths and vulnerabilities, as well as suggests some measures for improving emergency services and disaster management. As hospitals and health centers usually operate with little public funding or gross profit, the cost-benefit analysis guide can be a useful tool to gain the support of policymakers and managers to invest in sustainable practices and ensure planned interventions. Using this guide, users can reduce greenhouse gas emissions, and operating costs by decreasing water and energy consumption, and the impact of climate change. The organization is currently developing training guidelines for healthcare staff in the Caribbean, so that they are better prepared for emergency and disaster events (for example, the proper use of backup generators). Employee training should be done periodically, which can quickly improve the skills of employees. If staff is empowered and properly trained, they can help reduce the health risks of climate change and support adaptation measures [38].

Strengths and Limitations

This study has several important strengths. First, it provides one of the first qualitative explorations of climate-adaptive hospitals in Iran by capturing the perspectives of multidisciplinary experts with extensive experience in climate change, disaster risk management, healthcare management, environmental health, engineering, and hospital planning. The use of purposive sampling with maximum variation enabled the inclusion of diverse viewpoints, thereby enriching the findings. In addition, the application of conventional content analysis, together with rigorous procedures to ensure trustworthiness based on Lincoln and Guba's criteria, enhanced the credibility, dependability, confirmability, and transferability of the findings. The study also proposes a comprehensive framework integrating both climate adaptation and climate mitigation strategies, which may inform future policy development, hospital preparedness planning, and the design of climate-resilient healthcare facilities. Several limitations should also be acknowledged. As with most qualitative studies, the findings are context-specific and are not intended to be statistically generalizable. Although participants represented a wide range of relevant disciplines, all experts were recruited from Iran; therefore, the transferability of the findings to other healthcare systems should be undertaken with consideration of local contexts. Furthermore, most interviews were conducted virtually because of the COVID-19 pandemic, which may have limited the observation of non-verbal communication during interviews. Nevertheless, efforts were made to maintain interview quality through prolonged engagement, in-depth probing, and systematic data analysis until data saturation was achieved. Future studies may benefit from including experts from different countries and healthcare settings to further validate and refine the proposed framework.

Conclusions

Climate change is one of the most pressing global health challenges, making adaptation within healthcare facilities an urgent priority. This study identified key strategies and actions required to strengthen climate adaptation in hospitals, providing evidence that can support hospital managers and health policymakers in planning and implementing adaptation measures. Understanding and prioritizing these components is an essential first step toward reducing hospitals' vulnerability to climate-related hazards and improving the resilience of healthcare systems.

Integrating climate adaptation measures into hospital planning, design, construction, and daily operations can enhance resilience while promoting environmentally sustainable healthcare. The identified strategies emphasize the importance of resilient infrastructure, sustainable resource management, organizational preparedness, technological innovation, and workforce capacity building.

Based on these findings, a practical policy-oriented action plan can be developed to guide climate adaptation in hospitals. Such a plan should be refined through consultation with key stakeholders—including health authorities,

hospital managers, clinicians, engineers, environmental experts, and disaster management specialists—to ensure its feasibility and relevance before implementation at national or regional levels.

Overall, translating these findings into evidence-informed policies and operational guidelines has the potential to strengthen healthcare system resilience, reduce environmental impacts, and support sustainable health service delivery in the face of climate change.

Declarations

Competing interests

The authors announce that there is no conflict of interests as regards the research, compilation and publication of this article.

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Ethical Considerations

All practices were performed according to ethical considerations set by TUMS.

References

[1] Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet. 2009;373(9676):1693-1733. https://doi.org/10.1016/S0140-6736(09)60935-1

[2] Curtis S, Fair A, Wistow J, Val DV, Oven K. Impact of extreme weather events and climate change for health and social care systems. Environ Health. 2017;16(Suppl 1):23-32. https://doi.org/10.1186/s12940-017-0324-3

[3] Loosemore M, Carthey J, Chandra V, Chand AM. Climate change risks and opportunities in hospital adaptation. Int J Disaster Resil Built Environ. 2011;2(3):210-21. https://doi.org/10.1108/17595901111167097

[4] Séguin J, Berry P, Bouchet V, Clarke KL, Furgal C, Environmental I, et al. Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity. Ottawa: Health Canada; 2008.

[5] Mousavi A, Ardalan A, Takian A, Ostadtaghizadeh A, Naddafi K, Bavani AM. Health system plan for implementation of Paris agreement on climate change (COP 21): a qualitative study in Iran. BMC Public Health. 2020;20(1):1-13. https://doi.org/10.1186/s12889-020-09503-w

[6] Atwoli L, Erhabor GE, Gbakima AA, Haileamlak A, Ntumba JMK, Kigera J, et al. COP27 Climate Change Conference: urgent action needed for Africa and the world. Lancet Oncol. 2022;23(12):1486-8. https://doi.org/10.1016/S1470-2045(22)00645-3

[7] Bouley T, Roschnik S, Karliner J, Wilburn S, Slotterback S, Guenther R, et al. Climate-Smart Healthcare: Low-Carbon and Resilience Strategies for the Health Sector. Washington (DC): World Bank; 2017.

[8] World Health Organization. Healthy Hospitals, Healthy Planet, Healthy People: Addressing Climate Change in Health Care Settings: Discussion Draft. Geneva: WHO; 2010.

[9] Global Green and Healthy Hospitals. Global Green and Healthy Hospitals Agenda. 2015.

[10] Pan American Health Organization; Disaster Mitigation Program. Principles of Disaster Mitigation in Health Facilities. Washington (DC): Pan American Health Organization; 2000.

[11] Kubba S. Handbook of Green Building Design and Construction: LEED, BREEAM, and Green Globes. Waltham (MA): Butterworth-Heinemann; 2012. https://doi.org/10.1016/B978-0-12-385128-4.00003-2

[12] Zuo J, Xia B, Chen Q, Pullen S, Skitmore M. Green building rating for office buildings-Lessons learned. J Green Build. 2016;11(2):131-46. https://doi.org/10.3992/jgb.11.2.131.1

[13] BRE Global. BREEAM New Construction: Non-Domestic Buildings, Technical Manual SD 5076: 0.1 (DRAFT). Watford (UK): BRE Global; 2014.

[14] Algburi SM, Faieza A, Baharudin B. Review of green building index in Malaysia; existing work and challenges. Int J Appl Eng Res. 2016;11(5):3160-7.

[15] Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res. 2005;15(9):1277-1288. https://doi.org/10.1177/1049732305276687

[16] Elo S, Kyngäs H. The qualitative content analysis process. J Adv Nurs. 2008;62(1):107-15. https://doi.org/10.1111/j.1365-2648.2007.04569.x

[17] Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today. 2004;24(2):105-12. https://doi.org/10.1016/j.nedt.2003.10.001

[18] Thomas DR. A general inductive approach for analyzing qualitative evaluation data. Am J Eval. 2006;27(2):237-46. https://doi.org/10.1177/1098214005283748

[19] MacNaughton P, Cao X, Buonocore J, Cedeno-Laurent J, Spengler J, Bernstein A, et al. Energy savings, emission reductions, and health co-benefits of the green building movement. J Expo Sci Environ Epidemiol. 2018;28(4):307-18. https://doi.org/10.1038/s41370-017-0014-9

[20] Lee BK, Ellenbecker MJ, Moure-Eraso R. Analyses of the recycling potential of medical plastic wastes. Waste Manag. 2002;22(5):461-70. https://doi.org/10.1016/S0956-053X(02)00006-5

[21] Paraschiv M, Kuncser R, Tazerout M, Prisecaru T. New energy value chain through pyrolysis of hospital plastic waste. Appl Therm Eng. 2015;87:424-33. https://doi.org/10.1016/j.applthermaleng.2015.04.070

[22] FitzGerald GJ, Capon A, Aitken P. Resilient health systems: preparing for climate disasters and other emergencies. Med J Aust. 2019;210(7):304-5. https://doi.org/10.5694/mja2.50115

[23] Gerwig K. Greening Health Care: How Hospitals Can Heal

the Planet. Oxford: Oxford University Press; 2014. https://doi.org/10.1093/med/9780199385836.001.0001
[24] Paterson J, Berry P, Ebi K, Varangu L. Health care facilities resilient to climate change impacts. Int J Environ Res Public Health. 2014;11(12):13097-116. https://doi.org/10.3390/ijerph111213097
[25] Achour N, Price AD. Resilience strategies of healthcare facilities: present and future. Int J Disaster Resil Built Environ. 2010;1(3):264-76. https://doi.org/10.1108/17595901011080869
[26] World Health Organization. Health in the Green Economy: Health Co-Benefits of Climate Change Mitigation-Transport Sector. Geneva: WHO; 2012.
[27] Eckelman MJ, Sherman J. Environmental impacts of the US health care system and effects on public health. PLoS One. 2016;11(6):e0157014. https://doi.org/10.1371/journal.pone.0157014
[28] World Health Organization. Promoting Health While Mitigating Climate Change-Technical Briefing for the World Health Organization Conference on Health and Climate. Geneva: WHO; 2015.
[29] Ebi KL, Kovats RS, Menne B. An approach for assessing human health vulnerability and public health interventions to adapt to climate change. Environ Health Perspect. 2006;114(12):1930-4. https://doi.org/10.1289/ehp.8430
[30] Villalobos Prats E. WHO Guidance for Climate-Resilient and Environmentally Sustainable Health Care Facilities. Geneva: World Health Organization; 2020.
[31] World Health Organization. Safe Hospitals in Emergencies and Disasters: Structural, Non-Structural and Functional Indicators. Manila: WHO Regional Office for the Western Pacific; 2010.
[32] Cimellaro GP, Reinhorn AM, Bruneau M. Framework for analytical quantification of disaster resilience. Eng Struct. 2010;32(11):3639-49. https://doi.org/10.1016/j.engstruct.2010.08.008
[33] World Health Organization. Water, Sanitation and Hygiene in Health Care Facilities: Practical Steps to Achieve Universal Access to Quality Care. Geneva: WHO; 2019.
[34] Corvalan C, Villalobos Prats E, Sena A, Campbell-Lendrum D, Karliner J, Risso A, et al. Towards climate resilient and environmentally sustainable health care facilities. Int J Environ Res Public Health. 2020;17(23):8849. https://doi.org/10.3390/ijerph17238849
[35] Fallah-Aliabadi S, Ostadtaghizadeh A, Ardalan A, Fatemi F, Khazai B, Mirjalili MR. Towards developing a model for the evaluation of hospital disaster resilience: a systematic review. BMC Health Serv Res. 2020;20(1):1-11. https://doi.org/10.1186/s12913-020-4915-2
[36] Mashallahi A, Ardalan A, Nejati A, Ostadtaghizadeh A. Climate adaptive hospital: A systematic review of determinants and actions. J Environ Health Sci Eng. 2022;20(2):1-31. https://doi.org/10.1007/s40201-022-00810-5
[37] Zhong S, Clark M, Hou XY, Zang A, Fitzgerald G. Proposing and developing a definition and conceptual framework for health care resilience to cope with disasters. Emergencias. 2014;26(1):69-77.
[38] Balbus J, Berry P, Brettle M, Jagnarine-Azan S, Soares A, Ugarte C, et al. Enhancing the sustainability and climate resiliency of health care facilities: a comparison of initiatives and toolkits. Rev Panam Salud Publica. 2016;40(3):174-80.