Research for Action on Climate Change and Health in the Caribbean:
A Public, Private, People's and Planetary Agenda

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16. SMART HEALTH FACILITIES

16.1. WHAT IS HAPPENING?

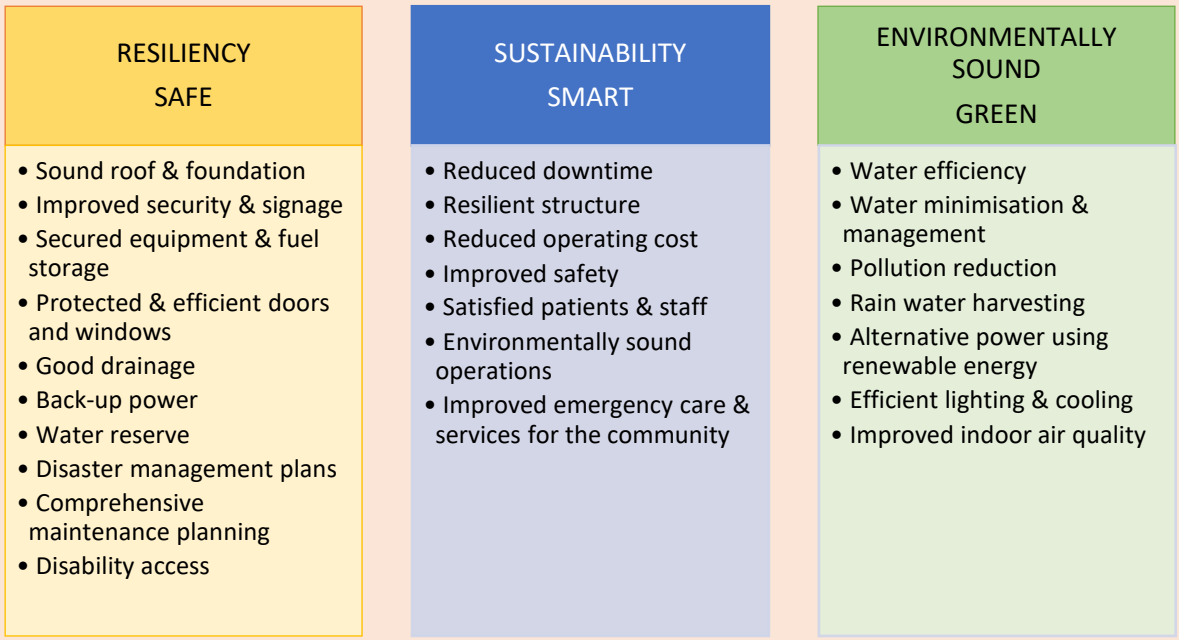
Climate change has the potential to have devasting health impacts across the Caribbean Small Island Developing States (SIDS) (CARPHA, 2017; EarthMedic/EarthNurse Foundation for Planetary Health et al., 2021; R4ACCHC, 2022a) (see Chapters 1, "Health impacts of extreme weather events", 2, "Vulnerability to vector-borne diseases", 3, "Water, sanitation and hygiene", 4, "Noncommunicable diseases and risk factors", 5, "Air quality", 6, "Heat-related illness ", 7, "Mental health", 8, "Population displacement and migration', 9, "Distribution, equity and justice in climate change and health", 12, "Agriculture and food safety and security", and 14, Marine resources and health"). Given the ever-increasing impacts of climate change on health, it is vital to have resilient health facilities capable of functioning during and after extreme weather events and designed to function in environmentally sustainable ways.

A major source of concern is the resilience of health facilities to natural disasters, of which hurricanes are one type. In the Americas, 61% of the impact on health facilities is caused by earthquakes, 17% by hurricanes, 14% by floods and 8% by other health emergencies (Buter, 2021). In 2010 Hurricane Tomas caused USD 2 million in damages to health facilities in Saint Lucia (ECLAC, 2011), and in 2017 the estimated damage to health infrastructure in Dominica after Hurricanes Irma and Maria was USD 10.3 million (Ministry of Health and the Environment, 2017). When 38 hospitals in the English-speaking Caribbean were assessed using the Hospital Safety Index (HSI; see Box 1), it was found that 82% of them could resist a disaster but the equipment and critical services were at risk, and 18% could not resist a disaster in that the lives and safety of occupants were deemed at risk in the event of a disaster (PAHO, 2017). In Latin America and the Caribbean 67% of hospitals are in areas assessed to be at high risk of natural disaster (PAHO, 2017). This is especially important, because 70% of health ministries' budgets are spent on hospitals.

Health systems globally are estimated to contribute some 5% of global greenhouse gas emissions, more than the total greenhouse gas emissions of Japan or Brazil, especially through energy use (Karliner et al., 2019). Health facilities use large amounts of energy. This contributes to greenhouse gas emissions and is excessively costly because Caribbean energy prices are among the highest in the world (PAHO, 2013). It is prudent to try to reduce this expenditure and use the resources instead to improve the health systems. Smart facilities focus on improving resilience, strengthening structural and operational aspects and using green technologies. Energy improvements include solar panel installations, electric storage batteries and low-consumption electrical systems. In addition to reducing energy consumption, these improvements reduce the health sector's carbon footprint and give hospitals energy autonomy, allowing them to continue running during and after emergencies and disasters.

Smart health facilities must be safe and green; they must link their structural and operational safety with green interventions at a reasonable cost–benefit ratio (see Figure 1). Other ways to be more environmentally friendly and sustainable include using eco-friendly flooring, paints, furniture and furnishings; using less paper; recycling; generating less waste; disposing of waste (solid and liquid) and pharmaceuticals properly; using environmentally benign chemicals; and sourcing more locally and sustainably produced food (PAHO, 2017, n.d.).

Figure 1: Elements of a smart health facility



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The Foreign, Commonwealth and Development Office of the United Kingdom Government (FCDO)[1] funded the Smart Health Care Facilities in the Caribbean (SHCFC) project: phase 1 (2012–2014) and phase 2 (2015–2022). This project was implemented by the Pan American Health Organization (PAHO) in collaboration with the ministries of health in target countries (Hassan, 2021; PAHO, n.d.). The overall aim of the project was to provide safer, greener healthcare facilities that could deliver care in times of disaster. It was implemented in seven countries: initially in two countries (Saint Kitts and Nevis and Saint Vincent and the Grenadines) and then expanded to another five countries (Belize, Dominica, Grenada, Guyana and Jamaica). The project had four main outputs (Hassan, 2021; PAHO, 2017, n.d.):

1. Assessing the disaster safety and water and energy consumption of health facilities;
2. Implementing standards in selected health facilities in Belize, Dominica, Grenada, Guyana, Jamaica, Saint Lucia and Saint Vincent and the Grenadines;
3. Developing national and regional capacity to promote climate-smart health facility standards for health workers and users of the facilities; other sectors and climate change platforms or programmes; technical stakeholders (construction, engineering, architects, etc.) and the media;
4. Improving accounts of reconciliation and transparency in financial reporting and implementing risk management.

Phase I introduced the concept “safe + green = smart” (Figure 1) and developed a smart toolkit with resources for identifying and implementing practical and measurable smart building design, operations and maintenance solutions for the Caribbean. This phase retrofitted health facilities in Saint Vincent (Georgetown Hospital) and Saint Kitts (Pogson Medical Centre) (Buter, 2021; PAHO, 2017, n.d.). Retrofitting included replacing windows to

[1]The FCDO was formerly called the United Kingdom Department for International Development.

combat higher wind speeds, strengthening roofs to accommodate solar panels, and improving natural lighting, ventilation, fire safety and emergency exits. Following the completion of the retrofit at the Georgetown Hospital, electricity consumption decreased by approximately 58% and that of the Pogson Medical Centre by 50% (Buter, 2021).

The toolkit provides guidelines for assessing, designing, and adapting or building new health facilities. It incorporates climate-smart and safety standards and includes three main sections: the HSI (see Box 1), the Baseline Assessment Tool (BAT) and the Green Guide. Annexes provide additional information that will assist in guiding health officials and health facility administrators in achieving smart health facilities[2] (PAHO, 2017, n.d.).

- HSI: the index is used to assess a health facility and determine whether it is disaster resilient and can continue to operate during a climate-related disaster based on structural, non-structural and functional factors. A health facility is scored on the level of safety in 145 areas. Based on the index score, the health facility is placed into one of three categories (PAHO, 2017):
    - Category A: a facility that is deemed able to protect the lives of its occupants and is likely to continue functioning in disaster situations.
    - Category B: a facility that can resist a disaster but in which equipment and critical services are at risk.
    - Category C: a facility where the lives and safety of occupants are deemed at risk during disasters.
- BAT: the tool is used to collect baseline information to assist in decision-making when retrofitting a health facility. Users of the tool need specialised structural and electrical engineering knowledge. The data gathered include energy and waste consumption; indoor environmental quality; building components; the results of an occupant survey; and local land use zoning regulations.
- Green Guide: the guide is a checklist that health facility operators can use to minimise their contribution to climate change. It identifies areas that can conserve energy, cut costs, increase operational efficiency and reduce the health facility's carbon footprint. The checklist has a maximum score of 100, with 70 being the minimum total score needed to achieve certification.

For a health facility to be considered "gold standard", it needs to achieve a combination of scores from the HSI and the Green Guide, which has been set at A/70 (PAHO, 2017).

Phase 2 of the SHCFC project assessed additional health facilities in Belize, Dominica, Grenada, Guyana, Jamaica, Saint Lucia and Saint Vincent and the Grenadines; built national and regional capacity to use and apply the smart toolkit; and retrofitted at least one health facility in each of the participating countries. This led to enhanced safety standards, reduced downtime and damage to health facilities from natural disasters, and lower operating costs due to savings on water and electricity (Baron, 2021; Buter, 2021). See Box 1 for a case study of smart adaptation and mitigation strategies at health facilities in Saint Lucia. Training in water and energy conservation and contingency planning has resulted in new habits and staff better prepared for emergencies. Data collected in the community surrounding the Vieux-Fort Wellness Centre has demonstrated desirable changes in knowledge, attitudes and practices (Harvey, 2021).

[2]Annexes include "Sustainable construction: designing for the future", "Model policy for smart health facilities", "Green checklist and field guide", "Cost-effectiveness analysis: the Retrofitting Economic Support Tool (REST)", "Water conservation plan template and posters" and "Energy conservation plan template and posters".

Box 1: Smart adaptation and mitigation strategies and challenges at health facilities in Saint Lucia

In Saint Lucia three health facilities – Comfort Bay Senior Citizens Home, Vieux-Fort Wellness Centre and New Beginnings Transit Home – were retrofitted to A/70 standard. Twelve smaller facilities were also upgraded to an increased level of resilience and greenness. The following are some of the adaptation and mitigation strategies used:

- Adaptation to hurricanes: focusing on wind resistance, use of locally made timber shutters, as well as imported hurricane-rated aluminium shutters.
- Adaptation to drought and heavy rainfall: use of rainwater harvesting in response to drought and to direct and control the runoff of heavy rainfall. The runoff can be treated and used for clinical, sanitary and laundry purposes. A combination of gravity-fed and pumped systems was used.
- Adaptation to high temperatures: use of ventilation and solar-powered fans, as well as shading from photovoltaic panels.
- Mitigation: water and electricity consumption was reduced, with the reduction in electricity use being more marked when using solar photovoltaic systems.
- Mitigation: use of a specific budget for preventive maintenance.

Source: Harvey (2021).

Smart standards are being increasingly used in the Caribbean. Apart from the FCDO, other financial partners (e.g. World Bank, International Development Bank, European Union) have provided loans or grants for new builds or retrofits of health facilities. These projects have been implemented in the original seven countries of the project and also across the region in the Bahamas, the British Virgin Islands, Haiti, Montserrat, Sint Maarten and Suriname, for example. Box 2 presents a case study from the British Virgin Islands.

It should be noted that the Caribbean region's building codes are rather general. In the absence of national or regional policy to adopt smart building codes for health facilities, there is the risk that the implementation of smart builds or upgrades will be sporadic and subject to local capacity and willingness of governments (Julian Murray Consulting, 2022). Furthermore, as climate change advances and brings more powerful storms and floods, building codes need to be updated to match.

Box 2: Case study on climate-smart renovation of the Adina Donovan Home for the Elderly after Hurricane Irma in 2017

The Adina Donovan Home for the Elderly in Tortola, British Virgin Islands, was substantially damaged by Hurricane Irma in 2017. The home sustained severe damage to its roof, windows, hurricane shutters and metal doors (including the front doors). Parts of the electrical system were broken, including exterior lighting fixtures, junction boxes, switches and outlets, and air conditioners and their switches. The perimeter fence was also destroyed by the high winds. The home had 18 occupants, and since it was one of only two care homes for older people on the island, getting it fully functional again was a matter of urgency. The Government of the British Virgin Islands with technical assistance from PAHO and funding from the United Kingdom Department for International Development used the PAHO smart toolkit to build back greener, smarter, and more resilient and sustainable. The following are some of the smart changes made to the home:

- Changes were made to ramps and louvered windows were included to allow safer movement of the residents and workers while also improving lighting.
- The roof was strengthened, and its slope increased. This was to improve its aerodynamic properties in anticipation of hurricanes with very high wind speeds in the future. Guttering was added to the roof that would direct captured rainwater into a cistern.
- The waterproof part of the roof was painted white (see image A below). This was to assist in reflecting light and heat off the roof, thus keeping it cooler and reducing heat transfer into the facility. Insulation sheets were also used on the new roof.
- A solar photovoltaic system was added to the front of the building and its panels placed on the roof (see image B below). The facility's energy consumption was reduced by approximately 20–30% by this system.
- LED bulbs were used throughout the facility to reduce energy and operating costs (see image C below).
- Inverter-type split air-conditioning units were added in some areas. These result in more energy-efficient cooling and thus reduced energy consumption. They also assist in improving indoor environmental quality.
- The kitchen was upgraded with a new energy-efficient refrigerator and a stove and oven combination.
- Low-flow toilets and aerated taps were added. These will assist in reducing water consumption and operating costs.

A: Roof painted white B: Solar panels on roof C: Use of LED bulbs

Source: Government of the British Virgin Islands et al. (2020); photos: copyright © Pan American Health Organization, 2020.

An evaluation report of the SHCFC project was released in December 2022. The following are the highlights of the findings (Julian Murray Consulting, 2022):

- The vulnerability of the target health facilities was substantially reduced.
- The project tested and proved a new model that added climate change adaptation and mitigation (green) to the established foundation of safety (safe). A new gold standard, A/70, for certifying resilience in health facilities was established.
- Public and government officials' knowledge increased but did not always translate into action. For example, it was found that some skills were gained, but it was not certain that enough of the correct people were trained to build a critical mass to ensure self-sustaining transformational change. Despite overt support from regional governments for smart facilities, there were instances in which they did not honour their commitments, for instance to purchase specific equipment or infrastructure to complement that provided by the funding partner, or to keep commitments on a timely basis.
- The project represented good value for money.
- Modest operating efficiencies were achieved, including increased energy and water conservation in retrofitted facilities.
- The British Virgin Island's system of smart accreditation for schools provides a viable model that could be replicated in the education and health sectors throughout the Caribbean region.
- Smart standards are being increasingly used in the region, but this is mostly as a result of the commitment of individuals rather than being underpinned by building or health regulations.
- The need for ongoing preventive maintenance of smart buildings remains a risk for their sustainability.

By June 2022, 415 Caribbean health facilities had been assessed using the smart toolkit; this has created an important database that can be used as a guide for future decision-making and to attract funding. Fifty-four facilities had been retrofitted and another six were in the pre-retrofit construction phase (i.e. the design stage). A total of 1,215 people had been trained in the use of the toolkit, the principles of conservation of water and energy, maintenance and contingency planning. Information about the project and its results have been communicated on social media, at conferences, on billboards and banners and through press releases. This has facilitated the implementation of the smart standards, attracted other financial partners (e.g. World Bank, International Development Bank and European Union) and promoted their use in other sectors (e.g. schools and a courthouse in the British Virgin Islands). The project resulted in approximately 500,000 people having access to more resilient health facilities during times of disaster (Buter, 2021; Julian Murray Consulting, 2022).

Important factors in the project's success and for the future of smart health facility projects include preventive maintenance and the use of "check consultants". Preventive maintenance helps ensure the success and sustainability of a smart health facility. The check consultants are a group of regional construction, structural, mechanical, electrical and plumbing engineers, architects and quantity surveyors who were used as and when needed. Check consultants were used at all stages of assessment and design to assist in troubleshooting and quality assurance. They were also used at the beginning of the project in the development of the toolkit and as trainers and at the end of the project for final validation of the quality of the work (Buter, 2021; Julian Murray Consulting, 2022). Box 3 lists the factors important in facilitating the SHCFC project. It has also been suggested that disaster management simulations are necessary to keep health facilities smart (R4ACCHC, 2023a).

Box 3: Facilitators of the implementation of the SHCFC project

- Preventive maintenance and use of check consultants;
- Strong, clearly understandable and measurable goals, e.g. attaining a resilience gold standard rating of A/70;
- Strong desire on the part of ministries of health and facility managers for upgrading;
- PAHO's capacity to conceptualise and implement a project of this scale and complexity, its strong relationships with national governments and the personal leadership skills of the project coordinator;
- Use of local experts and companies;
- A single project implementation unit based in Barbados, with local coordinators in each country;
- Good teamwork between the project implementation unit, local coordinators, ministry of health focal points and health facility managers and between PAHO and the FCDO;
- Adaptation strategies such as adjusting the HSI checklist for application to small and medium-sized facilities and adjusting design plans (e.g. focusing on use of space) and timelines (for delays in the arrival of raw materials) to account for the impacts of COVID-19.

Source: Julian Murray Consulting (2022).

A vision for scaling up the number of smart health facilities from 50 to 500 by 2030 has been articulated and proposes an expanded multi-stakeholder initiative including France, the Kingdom of the Netherlands, the United Kingdom and the United States of America, as countries that have dependent territories in the Caribbean region (Hospedales and van Alphen, 2022).

Apart from the PAHO smart toolkit, other initiatives that can be useful for Caribbean efforts to develop climate-smart health facilities and systems include the report *Delivering a Net Zero National Health Service* (NHS England and NHS Improvement, n.d.); and the work of Health Care Without Harm (Karliner et al., 2019), which aims to reduce the environmental footprint of health care. For primary care facilities, Greener Practice (United Kingdom) (Greener Practice, n.d.) and My Green Doctor (United States of America) (My Green Doctor, n.d.) are also useful free resources. The Aga Khan Development Network carbon calculator is a useful free tool for calculating and tracking the carbon footprint of healthcare operations (Aga Khan Development Network, 2021).

16.2. WHAT SHOULD BE DONE?

Individual and community actions and how to support them

Build awareness of the advantages of smart health facilities

For there to be uptake of smart (green + safe) health facilities, there needs to be increased awareness of the impact of climate change on health and health facilities and of the advantages of having smart health facilities. This need for awareness applies not only to the public but also to health facilities' managers, public and private, healthcare professionals, and the ministries responsible for urban planning, the environment and health. Social media, conferences, billboards and banners, and press releases were used to communicate the work and results of the SHCFC project. This had the added benefit of attracting financial partners to implement additional Caribbean projects, not only in the health sector, using the smart standards (Buter, 2021; Julian Murray Consulting, 2022; R4ACCHC, 2023a). Figure 2 shows a health centre in Saint Vincent and the Grenadines with a sign indicating to the public that it is a smart health centre. By building awareness, at individual, household and community levels, of the benefits of smart health facilities, it is hoped that smart standards will be used in developing structures other than health facilities. This is already being done in Saint Vincent and the Grenadines (R4ACCHC, 2023a,b).

Figure 2: Sign outside Barrouallie Smart Health Centre, Saint Vincent and the Grenadines

Source: PAHO et al. (2021); copyright © Pan American Health Organization, 2021.

Encourage health clinic attendance in the early morning and early evening

One of the impacts of climate change has been an increase in air temperature (see Chapter 6, "Heat-related illness"). Health clinics and hospitals should offer and encourage early morning (between 7:00 and 9:00 a.m.) and early evening (between 5:00 and 6:00 p.m.) appointments in addition to retaining the option to visit in between these times. Having fewer people at a health facility during the hottest time of the day can reduce the energy needed for cooling rooms.

Structural/governmental and private sector actions

Integrate smart standards in national and regional policies and guidelines

The goal that all health facilities should achieve the A/70 standard should be adopted. Smart standards (safe + green) must include preventive maintenance) and should be included in national and regional policies, strategies and codes relating to health, climate change and disaster risk reduction. This could include the

adoption of a national smart health facilities policy[3] (PAHO, 2013) and the 2017 Smart Technical Standards for Retrofitting as part of the PAHO Smart Hospital Facilities Toolkit (PAHO, 2017). Other channels include the development of national health action plans and Caribbean comprehensive disaster management targets (Drewry, 2021; Drewry and Oura, 2022; Julian Murray Consulting, 2022; R4ACCHC, 2023a).

Scale up the PAHO Smart Health Care Facilities in the Caribbean project

The 2012–2022 SHCFC project should be scaled up, building on the lessons learned. Some recommendations include (Hassan, 2021; Julian Murray Consulting, 2022; R4ACCHC, 2022b):

- Ensure that national governments have a dedicated unit with the capacity and authority to identify target facilities and to provide technical support for their retrofitting.
- Implement smart projects where feasible. Ideally projects require a committed government, a project management team with relevant technical expertise, a local project implementation unit with delegated authority to make substantive decisions and a flexible donor.
- Be flexible with timelines – sometimes there are setbacks, e.g. COVID-19 or even climate change disasters. Consultations, verification of building ownership, quality design and construction, and behaviour change also take time.
- Create a regional network of check consultants, ensuring that additional consultants are continually added to the network to ensure its sustainability.
- Pay attention to maintenance – prevention is cheaper and greener than cure – think about it from the start. Understand that maintenance is ongoing. Establish national standards for maintenance with practical, affordable and independent means of verification. Develop the capacity and a culture for maintenance. Ensure that facility managers "own" the newly retrofitted health facility, and therefore they will be more inclined to ensure its upkeep. Guarantee preventive maintenance by creating a system of responsibilities, resources and technical support that is controlled by the health facility manager.
- Use local resources with a focus on design quality.
- Promote wider use of photovoltaic systems with batteries in facilities where smart retrofits are being done.

Include smart standards in regional and national building codes

National building codes remain general, are rarely built into national standards, have no established inspection system and are generally not enforceable. The British Virgin Islands and Montserrat appear to be the only countries that have adopted smart standards in health and other sector regulations. Belize, Jamaica, Saint Lucia and Saint Vincent and the Grenadines have not fully adopted smart standards through changes in existing regulations, but they have included them in the terms of reference for new buildings or retrofitting projects in the health sector. Smart awareness and understanding have grown within the Caribbean engineering community through the check consultants and regional engineering bodies (Julian Murray Consulting, 2022; R4ACCHC, 2023a). Climate and health nongovernmental organisations and civil society organisations and health

[3]A national smart health facilities policy would be built on the principles of the SHCFC project – where smart = safe + green. Smart health facilities policies should also include strategies for preventive maintenance. A national policy would build on existing initiatives that ministries of health are already undertaking to make health facilities resilient to disasters and to contribute to national governments' priorities in disaster risk reduction and in adaptation and mitigation to climate change. Such a policy would provide a legislative framework that would earmark specific human, technical and financial resources to achieve its goal of smart health facilities (PAHO, 2013).

professional associations should strongly advocate climate-resilient health systems, including smart health facilities, as they would benefit staff and patient safety and well-being.

Accredit smart healthcare facilities

PAHO has a hospital accreditation process across Latin America and the Caribbean. Several countries are seeking international accreditation for their health facilities, which will assist in strengthening public and tourist confidence in national health systems. Smart healthcare accreditation ensures that the healthcare facilities are maintained to the A/70 standard. Belize and Jamaica are in the process of deciding upon a national smart accreditation process. The British Virgin Islands is the only Caribbean entity that has a smart accreditation system, but it is in the education sector. Its system of smart accreditation for schools provides a viable model that could be replicated in the education and health sectors throughout the Caribbean (Julian Murray Consulting, 2022; R4ACCHC, 2023a).

Train health professionals in adopting climate-responsive practices

Staff of health facilities need to be properly trained if the facilities themselves are to be truly smart – it is not just a matter of infrastructure, medical equipment, supplies and energy use. This means that climate change impacts on health must be built into the training curricula of all health professionals. See Chapter 13, "Awareness- and skills-building". As facilities are built and upgraded to smart standards, there should be a similar upgrading of staff skills, with special training of all staff categories (including allied health professionals, administrative and transport staff as well as medical staff) and integration of standards into job descriptions and responsibilities. Training should include disaster management, simulations, energy conservation and other environmentally sustainable practices. For example, anaesthetists could be trained in how to reduce their use of anaesthetic gases that also are greenhouse gases without compromising patient safety (R4ACCHC, 2023a).

Research gaps and how to address them

Determine the cost–benefit and cost-effectiveness of the regional Smart Health Care Facilities in the Caribbean project and of other national new build and retrofitted health facilities

Undertaking cost–benefit and cost-effectiveness analyses of retrofitting health facilities is key and will provide data that can be used in designing work to retrofit additional health facilities and in building a case for support from donors and lenders. This information should be disseminated to policymakers in the ministries responsible for health, the environment and urban planning (Hassan, 2021; R4ACCHC, 2022b, 2023a). The proposed research questions are as follows (Hassan, 2021):

- What is the cost-effectiveness and cost–benefit of the SHCFC project, as a whole and broken down by health facility, in each of the participating countries?
- How well do smart health facilities stand up to extreme climate events compared with facilities not designed and built or retrofitted to smart standards?
- What is needed to scale up the smart health facilities initiative in the Caribbean?
- How do we ensure sustainable funding for new build or retrofitted smart facilities if the initial funding is foreign based?
- How do we engage the private sector in funding smart facilities? Are there any private hospital associations and medical associations such as the Caribbean College of Family Physicians, with which governments can partner?

Determine the barriers to increasing government leadership and participation in implementing smart health facilities

To scale up the implementation of smart health facilities throughout the Caribbean, the government has an important role in providing leadership and financial support. This is a step towards addressing many of the research gaps and actions required (R4ACCHC, 2023a). Some research questions include (Hassan, 2021):

- How do we strengthen the capacity among government leaders to understand climate change and its impact on health and the urgency of addressing the issue. How do we identify and empower champions to help achieve this?
- How do we promote the importance of understanding that smart health facility policy development and implementation is a critical part of building resilient health systems?

Conduct studies that will enable certification of local materials

In Saint Lucia, locally sourced timber shutters have been used in buildings to protect windows that had breeze block openings with fixed wooden louvres and/or glazed windows. However, the locally made timber shutters had not been tested to international standards to certify their wind resistance. Therefore, the Vieux-Fort Wellness Centre used imported aluminium shutters that had an international wind resistance certification but were probably more costly (Harvey, 2021). Research needs to be conducted to allow certification of locally sourced-products.

Understand the challenges of preventive maintenance

It is important to understand how maintenance can be better addressed rather than waiting for problems to occur. Research questions could include (Julian Murray Consulting, 2022; R4ACCHC, 2023a):

- How can the value for money of preventive maintenance be measured and demonstrated? This would assist in building a case for donors and governments to take maintenance more seriously.
- What are the challenges of preventive maintenance, and are there innovative ways to address these challenges?

Invest in development of efficient plumbing system options suitable for Caribbean water supplies and pressure

Conservation of water and efficient water systems are required, e.g. water-efficient taps and toilets. Low-flow plumbing fixtures are water-saving devices designed to save water, energy and money. They were used in the retrofitting of health facilities in Saint Lucia. However, since the water supply was neither consistent nor of high enough pressure to effectively run such plumbing fixtures, many proved to be unsuitable. Investigations are needed to adapt existing low-flow plumbing technology to conditions such as those found in Saint Lucia and, potentially, the rest of the Caribbean, where there are also challenges of inconsistent water supply and low pressure (Harvey, 2021). Consideration should be given to ways of managing and possibly integrating different sources of water, such as that from mains, rainwater harvesting and wells (R4ACCHC, 2023a).

Investigate the effectiveness of alternative cooling and ventilation systems

If ventilation is modified and additional cooling features are included in health centre designs, their effectiveness should be monitored for any new challenges that might arise. For instance, in the Vieux-Fort Wellness centre in Saint Lucia, solar-powered fans and shading from the photovoltaic panels did not achieve the level of cooling required in the ceiling space. It was also found that a temperature differential between air-conditioned rooms and rooms with natural ventilation and fans resulted in moisture-related problems on the wall between the two kinds of room. These types of challenges need investigation (Harvey, 2021). The issue of air quality and

increasing levels of Saharan dust also needs to be researched to determine if air filtration needs to be part of ventilation systems for health facilities.

Additional research questions

The following research questions arise from the recommendations above:

- How can awareness be built about the advantages of smart health facilities among the general public, health facility managers, healthcare professionals and the ministries responsible for health, the environment and urban planning?
- Have smart standards been incorporated into national and regional policies and building codes?
- How can building codes be modified to ensure resilience to the wind speeds typical of category 5 hurricanes (R4ACCHC, 2022c)?
- Since the PAHO SHCFC project ended in 2022, how many additional health facilities have been retrofitted, newly built or started, but not yet completed, using the smart standards?

Surveillance gaps and how to address them

Monitor and evaluate preventive maintenance

Plans for maintenance of health facilities to climate-resilient standards should be developed and should be accompanied by monitoring and evaluation systems to ensure their sustainability and suggest areas for improvement. The maintenance plan must have a clear set of guidelines, practices, scheduled timelines, checklists, means of verification and indicators through which it is clear who is accountable for what aspects of maintenance (with incentives and consequences), and what sorts of operational maintenance need to be carried out by whom and how regularly (Julian Murray Consulting, 2022).

Monitor the efficiency of the smart healthcare facilities

The challenges faced in the Caribbean in implementing smart health facility models may be distinct from those faced in other parts of the world. A repository of structural, mechanical, electrical and plumbing problems that have occurred when using green technology (e.g. photovoltaic systems) in health facilities should be developed, including information on how they were overcome. Also included in the repository should be a cost of initial output and cost of specific repairs. Reports should be generated for use by other health facilities to inform their design and to aid troubleshooting. Ideally, data would be aggregated not only at national level but also at regional level so that countries can learn from each other's experiences. This information could be presented and discussed at national and regional meetings of professional bodies, including those of engineers (R4ACCHC, 2023a).

Research and surveillance capacity-strengthening needs

To address the research and surveillance needed to ensure the implementation of smart health facilities, capacity must be built in implementation science and research, impact evaluation, and qualitative and mixed methods research. The following additional specialist expertise is required:

- Structural, mechanical, electrical and plumbing engineering;
- Quantity surveying;
- Architecture;
- Cost–benefit and cost-effectiveness analysis.

There is also a need for enhanced information technology infrastructure and expertise, along with surveillance expertise, to build the databases needed for sharing information. Communications specialists with writing skills are needed to make technical reports accessible to decision-makers. The involvement of medical associations

and healthcare facility managers and administrators will be important in future research and action (R4ACCHC, 2023a).

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