LANDSCAPE MAPPING
OF SPACE COOLING SOLUTIONS IN RURAL SUB-SAHARAN AFRICA AND SOUTH ASIA

NOVEMBER 2025

CONTEXT

As global temperatures rise, rural communities in Sub-Saharan Africa and South Asia face increasing risks from heat stress. These risks, compounded by intersecting challenges such as limited access to electricity, inadequate buildings and service infrastructure, and limited financial resources, exacerbate the vulnerability of these populations.

Despite the growing urgency, efforts to expand space cooling — referring to the process of creating a thermally comfortable indoor environment — have largely focused on urban areas, leaving rural populations underserved and the landscape of solutions poorly understood in terms of availability, affordability and contextual applicability.

This collaborative study aims to support policymakers, donors, and development actors to improve decision-making when designing and implementing space and thermal comfort cooling initiatives in rural areas.

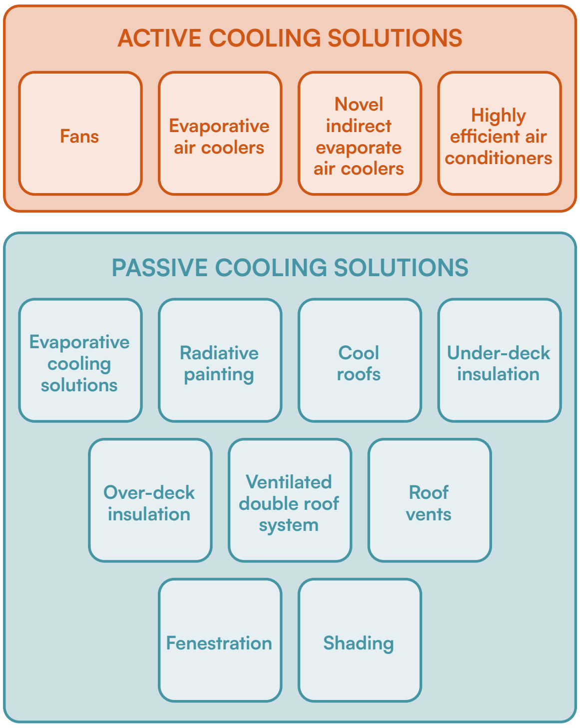

Figure 1. Diagram of mapped space cooling solutions

OVERVIEW

The paper maps a range of space cooling solutions applicable to rural areas, spanning from high-performing active solutions like off-grid air-conditioners and fans, to hybrid solutions such as active and passive evaporative cooling, and passive solutions including cool roofs and various types of insulation. It aims to assess the key factors that impact their use and implementation in different geographies and use contexts by compiling each solution's technical characteristics, market maturity, indicative costs, geographic availability, benefits, and challenges. Case studies from Sub-Saharan Africa and South Asia illustrate how these solutions have been implemented.

Assessing Applicability

To support decision-making, the paper proposes an applicability assessment framework composed of seven criteria that expand beyond cost, technology maturity and geographic availability of solutions. The table showcases examples of the analysis performed on four cooling solutions to understand the trade-offs and contextual factors that influence the success of space cooling interventions in rural areas.

		Performance in different climates	Ease of implementation	Quality assurance & maintenance	Ease of use	Supply chain resilience	Embedded greenhouse gas (GHG) emissions	Environmental impact at end-of-life
ACTIVE COOLING	**Off-grid fans**	Suitable for hot-dry and hot-humid climates. Limited effectiveness in extreme heat.	High. No need for special installation or refurbishment, but important that sizing is fit for use.	Quality standards exist. High influx of low-quality fans in unregulated markets.	Low complexity. Important that users are aware of risks of use in extreme heat.	Medium to low resilience to global supply chains, especially solar systems.	No refrigerants and low energy consumption. The solar system and batteries represent the emissions hotspot.	E-waste from electronic components, particularly batteries and solar PV panels require specialised e-waste management.
	Off-grid evaporative air coolers	Suitable for hot-dry climates.		Nascent market — lack of quality standards.	Medium complexity. Need for frequent water input and user maintenance of humid parts to prevent the growth of bacteria.			
PASSIVE COOLING	**Cool roofs**	Suitable for hot-dry and hot-humid climates.	Medium. Needs customisation to specific use-case and some options require skilled masons for installing.	Quality standards are nascent globally. Repainting or re-coating every three — five years is needed.	Medium complexity. No user management beyond frequent cleaning and maintenance.	High resilience to global supply chains. Most materials are available locally.	Low embedded GHG emissions if solutions use locally available materials. If chemical-based coating is used for radiative barriers, embedded GHG emissions rise.	Most materials have no disposal impacts, but chemical-based coatings may contain per- and polyfluoroalkyl substances (PFAS) and need special disposal.
	Ventilated double roof systems	Very effective in hot-dry climates but suitable for hot-humid too.	Low. Needs customisation to specific use case and requires a roofing structure and skilled installers.	No standards exist. Quality assurance of installation is critical as it is part of the building's structure.	Low complexity. No user management needed.			

DESIGN FRAMEWORK

Cooling is not just a technical challenge, it is a design practice that needs tailored solutions per use case and requires us to negotiate between material and technology availability, climates, cultural expectations, individual and collective behaviours, and economic constraints. A value-based design framework ensures that interventions are not simply technically feasible, but that they are also socially just, environmentally friendly, inclusive, and economically viable.

1. **Design for socio-cultural value** — Solutions should reflect local traditions and lifestyles, ensuring technologies are not only functional but culturally acceptable and co-developed with communities.
2. **Design for environmental value** — Solutions should minimise lifecycle emissions and waste, prioritise locally available and regenerative materials, and integrate a combination of passive and active solutions to enhance effectiveness, long-term sustainability and resilience.
3. **Design for inclusivity** — Solutions should be co-created with people who are most affected by heat, ensuring they reflect diverse needs, empower the communities they serve through training and participation, and are economically viable either by being low-cost or through accessible financing and support for local livelihoods.

Satisfied solar-powered fan customer in Bangladesh. Credit: CLASP

KEY RECOMMENDATIONS AND CALLS TO ACTION

1. INTEGRATE SPACE COOLING FOR RURAL COMMUNITIES INTO DEVELOPMENT AND CLIMATE AGENDAS

Space cooling is a critical adaptation need for people living in off- or weak-grid rural areas. Integrating interventions into broader climate and development strategies and aligning goals with climate resilience and energy access is essential to bridge the rural cooling gap.

2. IMPLEMENT HUMAN- AND PLANET-CENTRED DESIGN APPROACHES TO ADVANCE EQUITABLE AND SUSTAINABLE SPACE COOLING INTERVENTIONS

Designing for thermal comfort is not only a technical challenge. Value-based design frameworks that prioritise socio-cultural relevance, environmental sustainability, inclusivity, and economic viability are also critical.

3. CONSIDER PASSIVE COOLING AS FOUNDATIONAL, AND SOLAR-POWERED ACTIVE COOLING APPLIANCES AS COMPLEMENTARY

Passive cooling should be prioritised to help meet cooling needs in rural settings, due to its cost-effectiveness and suitability to local contexts. Solar-powered active cooling appliances should be promoted to address residual cooling requirements where passive methods are insufficient, and in critical contexts such as in healthcare facilities, extreme heat and during heatwaves.

4. INVEST IN RESEARCH, DEVELOPMENT AND DEMONSTRATION TO IMPROVE AFFORDABILITY AND PERFORMANCE OF EMERGING TECHNOLOGIES

Emerging technologies like high-efficiency solar-powered air conditioners and evaporative coolers can be highly effective providing thermal comfort in critical contexts, but they require further innovation to reduce their cost and adapt them to rural settings. Pilot projects in public buildings can help support the assessment of their feasibility in different contexts and climates.

5. PROMOTE CROSS-REGION KNOWLEDGE TRANSFER AND ADAPTABILITY OF SPACE COOLING SOLUTIONS

Passive cooling techniques such as the use in India of mosaics as a radiant barrier, show promise for cross-regional use. Evaporative coolers, more widely available in on-grid settings in South Asia, have potential for uptake in off-grid hot-dry regions.

6. SUPPORT LOCAL ECOSYSTEMS FOR DESIGN, INSTALLATION, MAINTENANCE AND REPAIR TO ENABLE SUSTAINABLE JOB CREATION

To scale sustainable space cooling solutions effectively and sustainably, it is essential to build local capacity across the value chain - from masons and carpenters to manufacturers and architects.

7. SUPPORT INNOVATION AND PILOT PROJECTS TO DEMONSTRATE TRADITIONAL PASSIVE COOLING TECHNIQUES

Many passive solutions are rooted in traditional architectural techniques which have been displaced by standardised construction methods. There is potential for recovery and innovation of traditional passive cooling techniques to increase their potential for scale.

8. ASSESS SUPPLY CHAIN DEPENDENCIES WHEN DESIGNING COOLING INTERVENTIONS

Many cooling solutions, particularly active ones, rely on global supply chains, which impacts their cost, availability and environmental impact. It is key to support and invest in local manufacturing of both passive and active cooling components.

9. CREATE AWARENESS CAMPAIGNS AND RESOURCES THAT PROVIDE CLEAR GUIDANCE AND SUPPORT FOR INTEGRATING PASSIVE AND ACTIVE COOLING SOLUTIONS FOR IMPLEMENTERS AND END-USERS

Fans and evaporative coolers are often easier to install than passive cooling solutions. While they provide some thermal comfort, their effectiveness can improve when used adequately and alongside passive cooling solutions. Awareness supports better choices in cooling system selection and installation.

10. EXPAND QUALITY ASSURANCE FRAMEWORKS TO ENSURE EFFECTIVENESS AND RELIABILITY OF SPACE COOLING SOLUTIONS

Quality assurance is a key challenge in scaling space cooling. Inadequate standards and quality control can lead to markets being flooded with low-quality products, hindering user adoption and trust. The lack of rural-specific building codes limits adoption and impact for passive cooling.

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