Nigeria Sokoto Health Systems Adaptation Options

Technical report

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GLOBAL CENTER ON ADAPTATION

This series of GCA Learning from Practice notes provides a practical reference to support the design and implementation of climate adaptation analyses. Drawing on the experience and lessons from GCA programs, each note focuses on a specific methodological component, offering guidance on key concepts, minimum standards, and recommended practices to strengthen the quality, consistency, and usability of analytical outputs.

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AUTHORS & ACKNOWLEDGMENTS

This report was developed by:

Global Center on Adaptation: Edwina Mercer, Senior Program Officer, Infrastructure and Nature-based Solutions; Gerald Leppert, Senior Economist, Research for Impact; Anne-Laure Solnon, Senior Specialist, Infrastructure and Nature-based Solutions; Folake Kareem, Program Officer, Research for Impact, in coordination with Adele Cadario (Global Lead, Infrastructure and Nature-based Solutions, Research For Impact).

GlobalCad: Johanna Klein; Guy Felio; Frank Müller; Nosah Bahago; Mara Ferrari; Andrea Tapia; Marco Guzzetti; Yassine Dziri; Fabian Berástegui; Mikel Sarasua.

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GLOBAL CENTER ON ADAPTATION

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ABBREVIATIONS

Acronym	Definitions
AC	Air Conditioning
AM	Asset Management
ATS	Automatic Transfer Switch
BCR	Benefit Cost Ratio
BS	British Standards
CAPEX	Capital Expenditure
CHEWs	Community Health Extension Workers
CHVA	Climate and Health Vulnerability and Adaptation Assessment.
CHWs	Community Health Workers
COPD	Chronic Obstructive Pulmonary Disease
CRA	Climate Risk Assessment
CRVA	Climate Risk and Vulnerability Assessment
CRV	Capital Replacement Value (applies to assets or equipment)
EMIS	Energy Management Information System
EN	European Norm
ER	Emergency Room
ETA	Estimated Time of Arrival
FCI	Facility Condition Index
FMoH	Federal Ministry of Health
FNPH	Federal Neuro-Psychiatric Hospital
GCA	Global Center on Adaptation
GH	General Hospital
GIS	Geographic Information System
HNAP	Nigeria's Health National Adaptation Plan
HVAC	Heating, ventilation, and air conditioning
ICU	Intensive Care Unit
IEC	International Electrotechnical commission
IHC	Illah Health Clinic
IsDB	Islamic Development Bank
ISO	International Organization for Standardization
LGA	Local Government Areas

MNCH	Maternal, New-born and Child Health
NBS	Nature Based Solution
NFPA	National Fire Protection Association
NiMet	Nigeria Meteorological Agency
NPI	National Programme on Immunisation
O&M	Operation and Maintenance
OPEX	Operations Expenditure
ORS	Oral Rehydration Salts
PHCs	Primary Health Centres
PHCUOR	Primary Health Care Under One Roof
PM	Preventive Maintenance
PM2.5	Particulate matter with a diameter of 2.5 micrometres or less
PPM	Planned Preventive Maintenance
PQS	Performance Quality Standards (WHO)
SEMA	State Health Emergency Management Agency
SOP	Standard Operating Procedure
SSP	Shared Socioeconomic Pathways
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

EXECUTIVE SUMMARY

Context and Objectives

Sokoto State's health system operates under significant structural and operational constraints — unreliable electricity, fragile cold-chain systems, weak referral mechanisms, poor cold chain management and outdated storage facilities— that already affect the health system functionality and access to services under current conditions. Climate change is expected to further increase the pressure on the system by intensifying hazards that directly affect health facilities, supporting infrastructure, and service continuity.

This report identifies, analyzes, appraises, and prioritizes green and grey adaptation and resilience measures that address the climate risks to health system assets and services in Sokoto State as identified by the findings of two preceding workstreams:

- The asset-level Climate Risk and Vulnerability Assessment (CRVA), which examined the direct impacts of climate hazards on existing healthcare assets and their components; and
- The network-level disruption analysis, which assessed how climate hazards affect the functionality, interdependencies, and continuity of healthcare delivery across the existing wider health system, including referral pathways, pharmaceutical supply chains, and essential supporting systems.[i]

Overview of Key Climate Risks

The most relevant hazards for the continuity of the health system infrastructure are extreme temperatures, heatwaves, and flooding. Extreme temperatures are projected to intensify across the state, with key operational implications for power supply and cold-chain vulnerability. Heatwaves lead to prolonged periods of sustained thermal stress across health facilities, with critical implications for staff performance and temperature-sensitive services. Flooding directly affects facilities, road accessibility and may disrupt referral systems, pharmaceutical supply chains, and access to essential services.

Across the assessed portfolio, Primary Health Centres (PHCs) present the most consistently severe climate risk profiles. Cooling is often limited to fans, and in some cases, such as Illah Health Clinic, there is no Heating, Ventilation, and Air Conditioning (HVAC) or cold storage at all. Energy system fragility is a cross-cutting vulnerability: where no power is available, there is no basis for immunization and other temperature-sensitive services. Where partial solar energy supply is available, high operational and extreme functional risk under heatwaves remain a concern. Flood exposure varies significantly across facilities, with Illah Health Clinic and Tudun Faila PHC projected to be the most affected among the assessed PHCs. Poor asset condition amplifies vulnerability: Giran Gero Health Clinic, where a major part of the structure has already collapsed, represents the most acute case. Secondary and tertiary facilities demonstrate stronger climate resilience profiles, but remain exposed to system-level risks through network dependencies, congestion, and in the case of Illela General Hospital, a single-point dependence on solar power with no generator backup.

Climate change resilience is unevenly distributed across the health system assets. Tertiary and some secondary facilities demonstrate functional resilience mechanisms, while PHCs, especially in rural areas, lack critical infrastructure and system redundancy. This gradient, from the Federal Neuro-Psychiatric Hospital's (FNPH) multiple energy sources to Illah Health Clinic's complete absence of power and cold chain, defines the differentiated adaptation investment strategy set out in this report.

Adaptation and Resilience Options

The report presents adaptation measures across five areas, addressed at both asset and network level.

Asset-specific adaptation options are sorted by type of hazard.

For extreme heat and heatwaves, which affect all facility types, measures include passive cooling elements (cool and reflective roofs, overhangs, cross-ventilation openings, and thermal insulation) during rehabilitation or new construction; bio-based insulating materials such as cow-dung plaster on exterior walls and roofs; shade tree planting using drought-resistant species such as Neem around west and south façades, waiting areas, and cold-chain rooms; vegetated shading structures on walls; and heatwave response protocols covering adjusted working hours, staff rotation schedules, hydration management, and service reduction criteria. For secondary facilities, expansion of solar power capacity and installation of at least one air-conditioned room per ward (prioritizing maternity, labour, and paediatric areas) is identified. For the tertiary facility (FNPH), upgrading and expanding existing air conditioning systems with indoor temperature monitoring is recommended. For warehouses, full insulation, air conditioning, and continuous temperature monitoring with automated alerts are treated as critical infrastructure requirements.

For wildfire, measures include operational guidelines for the fire season, PM2.5-rated window screens and ventilation filters, defensible fire buffer zones, and fire-resistant perimeter planting.

For pluvial flooding, measures include repair of damaged roofs, walls, and foundations with flood-resilient materials, with Giran Gero Health Clinic as the immediate priority given its structural collapse risk, raising critical electrical infrastructure above the assessed 1:100 flood depth, site drainage rehabilitation, and facility-level flood response plans with pre-identified cold-chain relocation protocols and communication trees.

Energy resilience is identified as a cross-cutting risk driver across all hazard categories and is addressed as a dedicated strand. The central measure for all immunizing PHCs is installation or upgrade of solar PV systems with sufficient battery storage and WHO PQS-certified cold-chain refrigerators, with a minimum specification of 48-hour battery autonomy for cold-chain loads. For Illela General Hospital, installation of a diesel generator with automatic transfer switch is proposed as backup to the existing solar system. For FNPH, expansion of solar plant capacity and upgrade of battery storage are recommended. A state-level Energy Management Information System (EMIS) providing real-time visibility of power status across the health facility network is identified as a medium-term systemic measure.

Asset management and life-cycle considerations are presented as a foundational adaptation measure underpinning all other interventions, given that poor maintenance amplifies vulnerability even under moderate hazard exposure. Recommendations include structured facility condition assessments using standardized scorecards, transition from reactive to planned preventive maintenance, development of a Facility Condition Index (FCI) for the Sokoto health real estate portfolio, and climate-proofing design standards applied during all rehabilitation works.

Adaptation options for road disruptions address flood-related impacts on referral and supply chain corridors at the network level. Four nature-based solutions are identified: grassed infiltration swales, vegetated gabions, vegetated terraces, and vegetated check dams, implementable either at road level or at floodplain scale as part of a broader landscape-based approach.

Institutional and capacity-building measures cover both asset and network levels. At the asset level, key measures include energy prioritization protocols, manual temperature logging, cold-chain breach and transfer protocols, seasonal stockpiling rules, patient surge protocols, and facility-level drills. At the network level, measures address flood-related coordination between facilities: pre-mapped referral corridors and fallback routes, pre-agreed transport rosters, referral coordination protocols with capacity status signaling, and pre-rainy season network drills. In consideration of the potential impacts of high political turnover and frequent administrative discontinuities, all operational measures are designed as simple, repeatable systems embedded in routine facility operations rather than relying on individually retained technical knowledge.

Prioritization and Investment Strategy

Adaptation measures are assessed against cost relative to asset replacement value, effectiveness in reducing a given climate risk, benefit-cost ratio of the proposed option, and secondary considerations including implementation timeline, social equity, institutional feasibility, and environmental co-benefits.

The highest-ranked measures are predominantly low-cost, immediate to short-term, and nature-based or operational in character. Shade tree planting, bio-based insulating materials, bio-swales and infiltration pits, passive cooling elements, wildfire season operational guidelines, PM2.5 window screens, heatwave response protocols, and facility-level flood response plans all combine low cost, medium to high effectiveness, and high benefit-cost ratios. A notable finding is the multi-hazard co-benefit profile of NbS measures: shade trees, bio-swales, and perimeter planting simultaneously address heat, flood, and fire risks, compounding their value relative to single-purpose grey interventions. Many of these measures can be mobilized in advance of formal capital investment cycles through community engagement and existing facility management.

Despite the strong case for low-cost measures, a set of higher-cost interventions is identified as essential for basic service continuity. Solar PV upgrades with WHO PQS-certified cold-chain refrigerators at all immunizing PHCs represent the most critical capital investment: without reliable, climate-resilient energy supply, cold-chain systems fail precisely during the heat events that increase vaccine demand. Raising electrical infrastructure above flood inundation levels at high-risk sites, and an emergency structural assessment at Giran Gero Health Clinic, are treated as preconditions for any rehabilitation investment at those facilities. Warehouse cold-chain protection through backup power, N+1 cooling redundancy, and continuous monitoring, is likewise classified as critical given the systemic implications of supply chain disruption.

In terms of implementation sequencing, the immediate group (0–2 years) addresses risks materializing now: structural safety at Giran Gero, electrical infrastructure elevation at flood-risk PHCs, solar and cold-chain upgrades across immunizing facilities, operational protocols before the 2027 dry season, warehouse monitoring, and fire buffer zone clearance before October 2026. The short-term group (2–5 years) covers systematic resilience infrastructure: cool roof retrofits, generator installation at Illela General Hospital, shade tree planting and bio-swale installation, temperature monitoring networks, and access road drainage improvement. Medium-term measures (5–15 years) address system-level transformation, including the EMIS, full Facility Condition Index reporting, and state-wide flood risk mapping across all 23 Local Government Areas (LGAs).

By combining immediately deployable, low-cost nature-based and operational measures with a sequenced programme of investments in energy resilience, structural safety and making its infrastructure more climate resilient, Sokoto State's health system can build the resilience needed to sustain essential service delivery as climate pressures intensify in the decades ahead.

1 INTRODUCTION AND CONTEXT

1.1 Assignment Background and Objectives

Sokoto State is located in North-Western Nigeria, bordering Niger and Benin. It covers about 32,000 km² and had a population of 4.2 million in 2009, around 80% of whom live in rural areas, mainly from the Hausa and Fulani groups. Health indicators show major sectoral challenges: only one in 20 children is fully vaccinated, infant mortality reaches 104 deaths per 1,000 live births, and fewer than 14% of the state's 852 health facilities have functional infrastructure. Many facilities lack the minimum readiness required to deliver essential services reliably, especially in rural areas where dependence on Primary Health Centers (PHCs) is highest. Key constraints include unreliable electricity supply, inadequate water access, limited cold-chain capacity, gaps in staff skills, weak referral mechanisms, poor cold chain management, outdated storage facilities, and frequent shortages of essential medicines. These constraints already affect health system functionality and access to services under baseline conditions and reduce the system's ability to maintain essential services under stress.

Climate change is expected to further increase this pressure by intensifying hazards that directly affect health facilities, supporting infrastructure, and service continuity. In this context, the most relevant hazards for the continuity of health system infrastructure are extreme temperatures, heatwaves, and flooding. Extreme temperatures are projected to intensify across the state, with key operational implications such as power interruptions and cold-chain vulnerability. Heatwaves lead to prolonged periods of sustained thermal stress across health facilities, with critical implications for staff performance. Flooding directly affects road accessibility and may disrupt referral systems, pharmaceutical supply chains, and access to essential services.

In response, the Islamic Development Bank (IsDB) is supporting the revitalization of Sokoto's healthcare system through investments in resilient health infrastructure and stronger supply chains.

As part of its support to the IsDB, GCA is developing a quantification of climate risks to existing and comparable health infrastructure under different climate change scenarios, supports the identification of green and grey adaptation measures, , and develops climate resilient technical guidelines for the planned healthcare infrastructures.

This report identifies, analyzes, appraises and prioritizes green and grey adaptation and resilience measures that address the climate risks to health system assets and services in Sokoto State. To this end, it builds on the findings of the previous workstream: the asset-level Climate Risk and Vulnerability Assessment[ii] and the network-level disruption analysis.[i]

The asset-level assessment examined the direct impacts of climate hazards on healthcare assets and their components through a climate stress test and vulnerability assessment, using representative asset archetypes for primary, secondary and tertiary facilities, as well as available information on the planned zonal medical warehouse.

The network-level analysis complemented this by assessing how climate hazards may affect the functionality, interdependencies and continuity of healthcare delivery across the wider health system, including referral pathways, pharmaceutical supply chains and essential supporting systems.

The outcomes of these two documents provide the analytical basis for the identification and appraisal of adaptation and resilience options in this report. The adaptation options and strategies identified in this report are further informed by recent evidence on climate-resilient health system design, encompassing the resilience of health value chains, healthcare service provision, and equitable access to care under intensifying climate pressures.[iii]

2 OVERVIEW OF CLIMATE RISKS TO THE SOKOTO STATE HEALTH SYSTEM

This chapter summarizes the key findings from Workstream 1 (which covers asset-level Climate Risk and Vulnerability Assessment and network-level disruption analysis) that are most relevant for this Adaptation and Resilience Options Appraisal Report. It provides the necessary information on the main climate risks affecting Sokoto State's health system that is needed for the elaboration of effective adaptation options. As adaptation is addressed at both asset and network level, the section covers asset-level vulnerabilities as well as network-level disruption pathways, with a specific focus on transport disruptions. The section is intended as a synthesis of findings only; readers are directed to the asset-level Climate Risk and Vulnerability Assessment and the network-level disruption analysis for full methodology, assumptions, scoring and detailed facility-level results.

Table 1 to Table 3 summarize the asset-level risk findings that are most relevant for the subsequent analysis of adaptation and resilience options. To this end, they present the main risk drivers, observed patterns in existing facilities, and potential consequences for representative primary, secondary and tertiary healthcare assets under the SSP5-8.5 mid-century scenario.[1] These summary tables are complemented by quantitative vulnerability matrices per asset and system type, which specify the type and severity of impacts on selected facility components, including physical damage, operational and maintenance impacts, lifespan reduction and functional or service delivery impacts.

[1] An SSP (Shared Socioeconomic Pathway) is a scenario describing possible future global development, created by an international community of climate researchers for the IPCC, while SSP5-8.5 is a specific high-emissions scenario based on fossil-fuelled growth leading to very strong warming by 2100

Table 1: Summarized Risk Analysis for Primary Health Centers (PHCs)

Risk Driver / Hazard	Observed Pattern in Existing Facilities	Potential Consequences
Extreme Heat & Heatwaves	PHCs have consistent severe risk profiles across the portfolio. Under SSP5-8.5, assessed PHCs face very high to extreme heat and heatwaves. Cooling is often limited to fans, in some cases (e.g. Illah Health Clinic) there is no HVAC or cold storage at all.	• **Where fans or limited cooling are available:** heatwaves can lead to indoor overheating, thermal discomfort, increased cooling demand and pressure on vaccine cold-chain systems. • **Where there is no air conditioning and no backup energy:** highly likely functional breakdown of thermal systems during heatwave episodes.
Energy System Constraints	PHCs show limited or absent energy access, with many with non-functional or poorly functioning solar systems. Grid connectivity and back-up systems are rare.	• **Where grid/solar connection exists:** electrical systems still reach high operational and functional risk under heatwave conditions. • **Where partial solar is available:** high operational and extreme functional risk under heatwaves remain a concern, consistent with the sensitivity of photovoltaic systems to extreme thermal stress. • **Where no power is available:** No basis for immunisation and other temperature-sensitive services at all.
Pluvial Flooding	Flood exposure varies significantly across PHCs. Tudun Faila PHC carries high pluvial flood hazard; Sarkin Adar Gidan Igwai has low exposure; PHC Dukamaje has no assessed flood exposure. Several PHCs are exposed to high pluvial flood risk, with Illah Health Clinic and Tudun Faila PHC projected to be the most affected.	• **Where flood exposure is high:** extreme risk scores occur for the roof, foundations and electrical systems; potential impacts include surface water ingress, foundation soils saturation and weakening, erosion around foundations, damage to floor slabs, electrical system hazards and access and infrastructure disruption. • **Where exposure is medium:** foundations and roof fall in the high-risk range, while walls and electrical systems generate moderate-to-high risk. • **Where exposure is low or N/A:** no equivalent facility-specific flood consequence is reported.
Site Runoff & Drainage	Flooding impacts are highly dependent on local topography, drainage conditions, and site characteristics. Some PHCs report flooding during the rainy season, part of the clinic flooded, or access roads closed during past events.	Where site conditions are poor, flooding impacts are disruptive rather than gradual, causing temporary facility closure, damage to buildings and equipment, and interruption of access roads and referral pathways.

Risk Driver / Hazard	Observed Pattern in Existing Facilities	Potential Consequences
Transport & Access Disruption	Transport and referral systems are highly sensitive to flooding, with many facilities relying on unpaved roads and informal transport modes. Some PHCs report that access roads have been closed during past events.	Access and connectivity risks may be as significant as asset-level risks. Flooding can cause interruption of access in roads and referral pathways; emergency referrals may be delayed or prevented.
Systemic / Network Risks	PHCs are the backbone of Sokoto's health service delivery model. They supervise community-level facilities, coordinate routine immunisation and outreach, manage uncomplicated deliveries, and serve as principal referral and reporting nodes at ward level.	• **Where condition is poor:** facilities are significantly more likely to experience structural failure, service disruption and accelerated deterioration under climate stress. • **Where condition is good:** buildings may still be exposed to high risks and require resilience measures, particularly for flood risks.
Asset Condition & Maintenance	PHCs range from partially collapsed, poor to good condition The climate risks report notes poor structural condition, aging buildings, cracks and partial collapse in some cases. Gidan Gero Health Clinic shows existing structural failure combined with flood exposure	Increased risk of equipment failure; reduced ability to absorb additional demand; dependence on external maintenance support during disruptions.
Functional Sensitivity	PHCs provide consultations, lab investigations, pharmacy, immunisation, treatment of common diseases and deliveries. Immunisation services depend on cold-chain systems; maternal and neonatal care require reliable electricity and functional facilities.	• **For immunisation services:** cold-chain infrastructure is highly exposed to temperature variability. • **For maternal and neonatal care:** service continuity depends on reliable electricity and functional facilities. • **For PHCs with limited functionality:** climate stressors may result in service interruption or complete failure.

Table 2: Summarized Risk Analysis for Secondary Health Facilities – Assessment of the Illela General Hospital

Risk Driver / Hazard	Observed Pattern in Existing Facility	Potential Consequences
Extreme Heat & Heatwaves	Illela General Hospital is exposed to very high to extreme heat and heatwave hazard under SSP5-8.5. Cooling is limited to fans and cold-chain storage for immunisation.	Indoor overheating / thermal discomfort; increased cooling demand; cooling system overload; HVAC rising to extreme functional risk under heatwaves; roof deformation and fatigue as well as accelerated aging from repeated thermal cycles are possible.
Energy System Constraints	The facility is off-grid. Key functions are powered by onsite solar PV, including maternity, immunisation, laboratory and theatre. No generator backup is available.	Risk of disruption to solar-powered critical functions, including maternity, immunisation, laboratory and operating theatre services; increased stress on electrical systems and solar panels; high operational and lifespan impacts, with extreme functional risk under heatwaves.
Transport & Access Disruption	Referral travel times from rural communities often exceed 1–3 hours in normal conditions.	Referral travel times are considerably more during floods or road disruptions.
Systemic / Network Risks	Secondary hospitals provide emergency obstetric care, caesarean sections, surgical interventions, inpatient services and laboratory diagnostics, but services are congested due to high case load.	Increased pressure on alternative facilities
Asset Condition & Maintenance	Structural condition is rated ‘good’. Medical equipment is basic and outdated. Solar panels are functioning properly, and maintenance is outsourced.	Roof exposure indicates moderate physical and lifespan risk from repeated thermal cycles.
Functional Sensitivity	Key functions depend on onsite solar power. HVAC is limited to fans and immunisation cold-chain storage.	HVAC (cooling and fans) reaches extreme functional risk under heatwaves; electrical systems reach high functional risk; solar panels show extreme functional risk under heatwaves.

Table 3: Summarized Risk Analysis for Tertiary Health Facilities- Assessment of the FNPH

Risk Driver / Hazard	Observed Pattern in Existing Facility	Potential Consequences
Extreme Heat & Heatwaves	The FNPH presents the most resilient risk profile among assessed facilities. It remains exposed to high climate risks under SSP5-8.5, but has fans, refrigeration and partial air conditioning in key areas.	Increased cooling demand; HVAC rising to extreme functional risk under heatwaves; roof deformation and fatigue. However, partial air conditioning reduces the probability of service interruption materializing in practice.
Energy System Constraints	The facility has grid connection, a solar plant and a standby generator. The solar plant supports sensitive areas, including the labour room, administrative block, ICU and immunisation unit.	Electrical systems reach high operational and functional risk under heatwaves; solar panels show high operational and lifespan impacts and extreme functional risk under heatwaves. Redundant energy supply reduces the probability of service interruption materialising in practice.
Transport & Access Disruption	Tertiary and specialised facilities provide specialist care, advanced diagnostics and health workforce training, supporting Sokoto State and neighbouring Kebbi and Zamfara.	Heightening pressure on services during climate-related disruptions.
Systemic / Network Risks	Primary, secondary and tertiary services are accommodated within the facility. The hospital supports a wider regional catchment.	Heightening pressure on services during climate-related disruptions.
Asset Condition & Maintenance	The facility is in Good to Very Good condition. Maintenance is carried out by the hospital's Works and Services Department. Solar panels are new and active; the generator works well; both systems are in good condition.	The roof shows moderate physical and lifespan risk under both heat-related hazards.
Functional Sensitivity	The solar plant supports sensitive areas, including the labour room, administrative block, ICU and immunisation unit.	Functional risk remains high-to-extreme across the portfolio because extreme heatwave hazard intensities are sufficient to stress even resilient systems.

Table 4: Summarized Risk Analysis for the new warehouse- Assessment of the FNPH

Risk Driver / Hazard	Observed Pattern in Existing Facilities	Implications for the Planned Warehouse	Potential Consequences
Extreme Heat & Heatwaves	System-wide exposure to very high to extreme heat; limited cooling capacity in most facilities	High and sustained cooling demand; risk of cooling system overload or inefficiency under future climate conditions	Temperature excursions affecting pharmaceuticals and vaccines; reduced system reliability
Energy System Constraints	Widespread unreliable electricity; dependence on solar with limited backup; no redundancy in many facilities	Critical dependence on uninterrupted power supply for cooling and operations; need for robust and redundant energy systems	Loss of temperature control; spoilage of stock; major operational disruption
Pluvial Flooding	Localized but high-impact flooding affecting buildings, drainage, and access roads	Risk of surface water accumulation on site; exposure of loading/unloading zones and ground-level storage; need for robust drainage	Disruption of logistics operations; water damage to goods and infrastructure; restricted access
Site Runoff & Drainage	Poor drainage systems increase vulnerability even under moderate rainfall	Large, paved areas (parking, truck movement) may increase runoff; requires enhanced drainage and water management design	Increased flood risk on-site; operational delays; infrastructure stress
Transport & Access Disruption	Flooding and poor road conditions disrupt referral and supply chains	Dependence on road access for distribution makes warehouse sensitive to external disruptions	Delays in delivery of medicines; breakdown of regional supply chain
Systemic / Network Risks	Interdependencies between facilities, energy, and transport create cascading failures	Warehouse acts as a centralized node; disruption would propagate across the health system	Widespread shortages of medicines and vaccines; reduced service delivery capacity
Asset Condition & Maintenance	Poor maintenance significantly increases vulnerability and accelerates degradation	Long-term resilience depends on maintaining high-performance systems (cooling, envelope, drainage)	Gradual loss of performance; increased failure risk during extreme events
Functional Sensitivity	Facilities already struggle to maintain basic service levels under stress	Warehouse operations require strict environmental control, making it more sensitive to disruptions	High consequence of failure compared to typical health facilities

In addition to these asset level risks, network level wide vulnerabilities can lead to important disruptions of the health care system in Sokoto State.iii

Energy instability is the single most consistent **system-wide vulnerability** identified in this study, affecting cold-chain integrity, pharmaceutical storage, and essential service operations at every level. Electrical supply reliability varies significantly across facilities. While tertiary facilities, such as the Federal Neuro-Psychiatric Hospital demonstrate resilience through multiple energy sources (grid connection, generator, and solar), the General Hospital Illela (secondary facility) relies primarily on solar power, which is functional but vulnerable during prolonged periods of low sunlight or extreme heat. At the PHC level, system fragility becomes evident; Tudun Faila PHC for example depends on grid electricity with a non-functional solar backup, creating a single-point failure risk. Illah Health Clinic on the other hand has no electricity or backup system, severely constraining service delivery, particularly under extreme heat conditions. This variability highlights a systemic decline in energy resilience from tertiary to primary care levels. Cold chain functionality follows a similar pattern. Temperature-controlled systems are maintained at tertiary and secondary health facilities' levels. However, PHCs operate under more fragile conditions. Tudun Faila PHC, for example, maintains cold chain operations but lacks backup power, exposing it to failure during outages. Illah Health Clinic lacks any cold chain infrastructure. Medicines are stored at ambient temperatures, and vaccines are sourced externally. This reliance introduces supply chain vulnerability and risks of service interruption. The findings point to a critical gap in last-mile cold chain reliability, with direct implications for immunization and treatment effectiveness.

Disruptions in the road network represent another **systemic failure risk** for Sokoto State health system. The disruption analysis undertaken for selected health facilities on the network level showed flood-induced travel times increase from 7.8 to 13.5 times. The primary impact is not infrastructure damage but restricted physical access to care. This underscores a gap in adaptation planning, where rural connectivity and referral systems are not adequately protected against climate risks.

3 EXISTING ADAPTATION POLICY FRAMEWORKS IN THE NIGERIAN HEALTH SYSTEM

Nigeria has established a growing policy framework to address the intersection of climate change and health, including the Climate Change and Health National Adaptation Plan (2025–2030) and the National Climate Change Policy (Table 5). These frameworks emphasize climate-resilient infrastructure, renewable energy integration, and strengthened health system preparedness.

Table 5. Key national policies and legal instruments in Nigeria supporting the development of climate-resilient health infrastructure

Instrument	Year	Key provisions for climate-resilient health infrastructure
Nigeria Climate Change Act[iv]	2021	Legally mandates climate adaptation plans across all sectors; establishes the National Council on Climate Change; net-zero target 2050–2070.
National Climate Change Policy 2021–2030[v]	2021	Operational framework for adaptation across sectors including health; calls for climate-proofing of public infrastructure and essential services.
National Health Act (amended)[vi]	2014/ 2022	Provides basic standards for health facility construction and equipment; increasingly invoked to justify climate-resilient upgrading of PHCs.

Instrument	Year	Key provisions for climate-resilient health infrastructure
Federal Climate-Health Policy (FMoH)	2024	Policy document developed by FMoH and stakeholders to mitigate climate change impacts on healthcare delivery; operationalises the CHVA recommendations. Based on the Nigeria CHVA Report (WHO/FMoH)[vii] (First national climate and health vulnerability & adaptation assessment; identifies priority adaptation actions for power, cold chain, flood risk, and WASH in health facilities using WHO's 10 building blocks framework)
Climate Change and Health National Adaptation Plan[viii]	2025	National roadmap developed by the Federal Ministry of Health and partners to mainstream climate adaptation in the health sector, strengthen resilience of health systems and infrastructure, and implement priority actions.

However, while these are promising developments, evidence from Sokoto State shows that uptake is nascent and state-level adaptation plans with dedicated financing and monitoring are yet to be enacted, indicating a persistent gap between policy intent and implementation, particularly at the primary health care (PHC) facility level in rural and high-risk settings. Overall, tertiary facilities show stronger alignment with these frameworks, while PHCs lack structured emergency preparedness, contingency planning, and system redundancy, reflecting a broader disconnect between policy frameworks and facility-level operational capacity.

Table 6 provides an overview of the policy commitments with the observed reality during field research of local experts from the consultant team in Sokoto State and its implications for the functionality of the health system.

Table 6 Comparison of policy commitments with observed reality in Sokoto State

Policy Area	Policy Commitment	Observed Reality	Gap	Implication
Power Supply	Federal Ministry of Environment Nigeria (National Climate Change Policy, 2021) promotes renewable energy (solar), backup systems, and resilient infrastructure in health facilities	Strong systems at tertiary level; weak or absent at PHCs	Uneven deployment; lack of redundancy	Service disruptions; reduced functionality
Cold Chain	Federal Ministry of Health and Social Welfare Nigeria (Climate Change and Health National Adaptation Plan 2025–2030) calls for strengthened cold chain systems and temperature-controlled storage	On the national level, there is a significant cold chain equipment gap, which is more prominent in Northern Nigeria. In Sokoto State the cold chain is mostly functional at higher levels; but weak or absent at PHCs	Poor last-mile infrastructure	Vaccine spoilage; interrupted services
Flood Management	National and subnational climate frameworks emphasize flood risk	Rural access disrupted during floods, urban drainage investments and	No protection of referral routes	Delayed care; increased health risks,

Policy Area	Policy Commitment	Observed Reality	Gap	Implication
	reduction, resilient infrastructure, and continuity of care	facility level flood proofing only reactive		including flood-related infectious diseases.
Emergency Preparedness	Federal Ministry of Health and Social Welfare Nigeria promotes health system resilience, emergency preparedness, and integrated service delivery	Weak or absent at PHC level	Lack of operational readiness	Inability to respond to shocks
Climate Integration	Federal Ministry of Health and Social Welfare Nigeria (HNAP 2025-2030) aims to integrate climate risk into health planning and service delivery	No structured response at facility level	Policy not operationalized	Rising demand without adaptation at facility level
State Governance	Sokoto State Government (emerging climate policy with partners) aims to strengthen resilience and coordination	Limited facility-level implementation	Early-stage, weak coordination	Fragemented roll out

4 ADAPTATION AND RESILIENCE INVESTMENT OPTIONS

This chapter presents information on potential adaptation measures to mitigate the impacts of the climate hazards on the assets and their components, as well as the services provided by these assets. It has been divided into asset-specific adaptation options for different hazards, options relevant for the resilience of energy systems, as well as options to decrease road disruptions relevant for referral pathways and distribution systems.

The chapter is accompanied by relevant considerations related to asset management, as well as institutional and capacity building measures relevant to accompany adaptation measures on the asset, as well as the network level.

4.1 Overview of asset specific adaptation options

This section provides a summary of the adaptation options applicable to all assets / components in the Sokoto State healthcare systems for the temperature-related hazards (extreme heat and heatwave) and wildfires since all assets are expected to be affected (mid-century, SSP5-8.5), as shown in Table 7 to Table 9.

Table 7. Examples of general adaptation measures - extreme heat

EXTREME HEAT				
Asset Type	Adaptation Measure	Solution Type	Implementation - Asset Management	Timeline
All PHCs (Primary)	Install passive cooling elements: cool roofs (reflective or vegetated), overhangs, and cross-ventilation openings during any rehabilitation or new construction. Target: indoor peak temperature ≤32°C.	Grey (Engineering)	Include cool roof specifications in all rehabilitation contracts. Prioritize facilities with metal roofs. Conduct condition assessments to identify facilities most exposed to overheating.[ix] [x]	Immediate (0–2 yrs)
	Install ceiling fans or mechanical ventilation in all consultation, delivery, and waiting rooms at a minimum. Pair with ventilation openings to enable stack-effect air movement.	Grey (Engineering)	Bundle with energy system upgrades. Establish maintenance agreements for all new mechanical systems installed at PHC level.	Immediate (0–2 yrs)
	Planting shade trees around buildings: Plant drought-resistant tree species (e.g., non-native: Neem (Azadirachta indica), or native: Afang/Okazi (Gnetum africanum)) around west/south façades, courtyards (green corridors), waiting areas, and near cold-chain rooms to provide shading and reduce heat gain (ambient temperature can be reduced as much as 2–5°C)	Green (Nature-Based)	Develop site-specific planting plans with local communities. Integrate tree maintenance into grounds management. Use community health workers for monitoring. [xi] [xii]	Short-term (2–5 yrs)
	Apply thermal insulation to existing walls and roofs during rehabilitation works; introduce double-skin or insulated roof panels in new construction. Target: reduce heat transfer coefficient (U-value) (typically ≤0.5 W/m²K for roofs).	Grey (Engineering)	Specify minimum thermal performance standards in rehabilitation procurement documents. Use locally available materials where feasible (clay brick, stabilized earth). [xiii]	Short-term (2–5 yrs)
Secondary (Illela GH)	Expand solar power capacity and install at least one air-conditioned room per ward, prioritizing maternity, labour, and paediatric areas. Size AC systems to maintain acceptable indoor temperature (typically ≤26°C) under 2050 peak daily temperatures.	Grey (Engineering)	Prioritize maternity and emergency areas for AC in CAPEX planning. Size AC against 2050 projections not current ambient temperatures. Ensure redundant backup power.	Short-term (2–5 yrs)
Tertiary (FNPH)	Upgrade and expand existing AC systems to ensure full coverage of all patient areas. Install indoor temperature monitoring system linked to facility management. Review performance against 2050 SSP5-8.5 projections.	Grey (Engineering)	Review existing AC capacity against 2050 projections. Install redundant backup cooling tied to the generator system. Establish thermal comfort monitoring dashboard.	Short-term (2–5 yrs)

EXTREME HEAT				
Asset Type	Adaptation Measure	Solution Type	Implementation - Asset Management	Timeline
Supply Chain (Warehouses)	Ensure all warehouse storage areas are fully insulated, air-conditioned, and monitored with temperature sensors (e.g., target: +2°C to +8°C for cold chain; +15°C to +25°C for dry ambient). Install backup generator with automatic transfer switch and 72-hour fuel reserve.	Grey (Engineering)	Treat temperature control as critical infrastructure. Establish performance guarantees. Install continuous monitoring with remote alerting.[xiv]	Immediate (0–2 yrs)
All Asset Types	Vegetated shading structures on walls: Install vertical wooden frames supporting drought-resistant climbing plants (e.g., bougainvillea) to shade walls and reduce indoor temperatures.	Green (Nature-Based)	Develop facility landscaping standards for all new and renovated health facilities, incorporating shading and cooling functions alongside biodiversity co-benefits.[xv]	Short-term (2–5 yrs)
	Use of bio-based insulating materials: Apply cow-dung-based insulation or other natural insulating plaster/paint on exterior walls/rooms, floors, and roofs to reduce heat transfer and offer thermal insulation	Green (Nature-Based)	Use local materials and support traditional skills. Periodic reapplication needed.[xvi]	Immediate (0–2 yrs)

Table 8. Examples of general adaptation measures - heatwaves

HEATWAVES				
Asset Type	Adaptation Measure	Solution Type	Implementation - Asset Management	Timeline
All PHCs (Primary)	Develop and implement heatwave response protocols: adjusted working hours, staff rotation schedules, hydration and heat illness management guidelines, and clear service reduction criteria. Align with Nigeria Meteorological Agency (NiMet) heat alert thresholds.	Grey (Engineering) — Operational	Include protocols in facility operations manuals. Train all managers and Community Health Extension Workers (CHEWs) in heat illness recognition and response. Review protocols annually before dry season.	Immediate (0–2 yrs)
	Construct shaded outdoor waiting and triage areas using pergolas with climbing drought-resistant vegetation (e.g., Vigna unguiculata, Lablab purpureus) or shade sails, to reduce patient heat stress and outdoor waiting-area temperatures by up to 8°C.	Hybrid (Grey + Green)	Incorporate outdoor shading in rehabilitation scope of work. Select plant species that are drought-tolerant and locally available. Design to allow natural airflow.	Short-term (2–5 yrs)
	Planting shade trees around buildings: Plant drought-resistant tree species (e.g., non-native: Neem (Azadirachta indica), or native: Afang/Okazi (Gnetum africanum)) around west/south façades, courtyards (green corridors), waiting areas, and near cold-chain rooms to provide shading and reduce heat gain (ambient temperature can be reduced as much as 2–5°C)	Green (Nature-Based)	Develop site-specific planting plans with local communities. Integrate tree maintenance into grounds management. Use community health workers for monitoring. [xixii xi]	Short-term (2–5 yrs)
Secondary & Tertiary	Establish dedicated 'cool zones' with reliable air conditioning in outpatient and waiting areas to serve as heat refuge areas for vulnerable patients (pregnant women, elderly, children) during peak heatwaves. Post signage. Operate cool zones on backup power during grid outages.	Grey (Engineering)	Designate and publicize cool zone locations. Ensure backup power maintains cool zones during grid failures. Define access policy (e.g., no appointment required during heatwave alert).	Short-term (2–5 yrs)
Supply Chain (Warehouses)	Install redundant cooling systems (N+1 minimum) and automated temperature alarms for cold-chain storage. Establish documented emergency protocol for heatwave-induced cooling failures, including pre-identified backup storage locations within 30km.	Grey (Engineering)	Require N+1 redundancy for all cooling systems. Test backup systems quarterly. Identify and pre-contract with backup storage providers. [xvii]	Immediate (0–2 yrs)

HEATWAVES				
Asset Type	Adaptation Measure	Solution Type	Implementation - Asset Management	Timeline
All Asset Types	Install real-time temperature and humidity monitoring systems (indoor and outdoor) to trigger response protocols and detect cold-chain risks. Link data to a state-level dashboard for early warning.	Grey (Engineering)	Establish alert thresholds (e.g., indoor temp >32°C triggers protocol; >35°C triggers service reduction). Integrate with existing health information system.	Short-term (2–5 yrs)
	Vegetated shading structures on walls: Install vertical wooden frames supporting drought-resistant climbing plants (e.g., bougainvillea) to shade walls and reduce indoor temperatures.	Green (Nature-Based)	Develop facility landscaping standards for all new and renovated health facilities, incorporating shading and cooling functions alongside biodiversity co-benefits.[xv]	Short-term (2–5 yrs)
	Use of bio-based insulating materials: Apply cow-dung-based insulation or other natural insulating plaster/paint on exterior walls/rooms, floors, and roofs to reduce heat transfer and offer thermal insulation	Green (Nature-Based)	Use local materials and support traditional skills. Periodic reapplication needed. [xvi]	Immediate (0–2 yrs)
	Retrofit buildings with heat-reflective exterior paint (e.g., Solar Reflectance Index ≥78) and phase out dark-colored metal roofing on all future construction. This single measure can reduce roof surface temperature by 30–40°C.	Grey (Engineering)	Add heat-reflective surface requirements to facility design standards and all future procurement specifications. [xviii] [xix]	Medium-term (5–15 yrs)

Table 9. Examples of general adaptation options - wildfires

WILDFIRE				
Asset Type	**Adaptation Measure**	**Solution Type**	**Implementtion - Asset Management**	**Timeline**
All Asset Types	Develop wildfire season operational guidelines: maintain adequate stock of salbutamol, antihistamines, and respiratory medications; prepare demand surge plans; establish referral protocols for smoke-related illness (asthma exacerbation, COPD, bronchitis).	Grey (Engineering) — Operational	Coordinate with the State Health Emergency Management Agency (SEMA). Pre-position additional respiratory medications before each fire season.	Short-term (2–5 yrs)
	Install window screens and ventilation filters (minimum PM2.5 rated) to reduce smoke and particulate matter intrusion into facility indoor spaces during fire season. Establish indoor air quality protocol when outdoor PM2.5 exceeds a selected threshold (typically 35 μg/m³).	Grey (Engineering)	Procure PM2.5-rated filters. Include filter replacement (every 3–6 months during fire season) in maintenance schedules. Train staff to switch to filtered indoor ventilation during smoke events.	Short-term (2–5 yrs)
	Establish low-cost air quality monitoring (e.g., PurpleAir or equivalent sensors) at facility level to trigger indoor protocols when PM2.5 thresholds are exceeded during fire season. Link to state early warning system.	Grey (Engineering)	Link sensor data to facility and state-level dashboards. Establish clear PM2.5 threshold levels for operational triggers. Share real-time data with NiMet.	Medium-term (5–15 yrs)
All PHCs (Primary)	Plant fire-resistant species in perimeter buffers and along access roads: neem (Azadirachta indica), acacia (Acacia senegal), and moringa (Moringa oleifera) — locally established species with high moisture content and low flammability.	Green (Nature-Based)	Partner with local and state forestry services for species selection and planting. Include perimeter vegetation maintenance in community engagement programs. Source seedlings from existing state nurseries.	Short-term (2–5 yrs)
	Create defensible space: cleared vegetation buffer zones (minimum 10m) around facility perimeters, maintained annually at the start of the dry season (September–October). Replace dry grasses near structures with low-flammability ground cover.	Hybrid (Grey + Green)	Assign dry-season vegetation management to facility maintenance schedules. Train groundskeepers on fire-safe landscaping. Budget for annual dry-season clearance.[xx]	Immediate (0–2 yrs)
Supply Chain (Warehouses)	Ensure warehouse perimeters are cleared of flammable materials; install fire suppression systems (sprinkler or gaseous suppression for cold-chain areas) and fire-rated external cladding on new warehouse construction. Comply with Nigeria Building Code[xxi] fire separation requirements.	Grey (Engineering)	Include fire safety in warehouse design review process. Test suppression systems every 6 months. Ensure fire extinguisher placement and staff training meet NFPA 10[xxii] standards.	Short-term (2–5 yrs)

Some asset locations are prone to impacts from climate hazards that are specific due to, for example, a low topography (e.g., pluvial flooding). For these, location-specific adaptation measures have been identified as follows (Table 10).

Table 10. Examples of asset-specific adaptation measures - pluvial flooding

PLUVIAL FLOODING				
Asset Type	Adaptation Measure	Solution Type	Implementtion - Asset Management	Timeline
All PHCs (Primary)	Repair damaged roofs, walls, and foundations with flood-resilient materials: waterproof cement render (typically, minimum 10mm), damp-proof membranes at floor level, reinforced concrete ring beams at lintel level. Priority: Giran Gero Health Clinic (structural collapse risk — requires full structural assessment before any works)	Grey (Engineering)	Conduct structured condition assessments across all PHCs annually. Commission structural engineering assessment at Giran Gero immediately. Prioritize facilities where flooding is already observed.[xxiii] [xxiv]	Immediate (0–2 yrs)
	Rehabilitate or construct bio-swales — vegetated drainage channels lined with drought-resistant grass species (e.g., Vetiver, Napier grass) — around facility grounds to slow runoff velocity, filter pollutants, and reduce peak flood risk. Size to handle 1:10-year storm event	Green (Nature-Based)	Design bio-swales as part of facility landscape plans. Select species providing dual flood and heat co-benefits. Community maintenance assignment to ensure vegetation cover year-round [xxv] [xxvi]	Short-term (2–5 yrs)
	Conduct pluvial and fluvial flood risk mapping at LGA scale to identify high-risk sites, inform future facility siting decisions, and prioritize investment across the PHC network. Commission in partnership with NIHSA and SEMA	Grey (Engineering) — Planning	Engage NIHSA and SEMA in risk mapping. Use outputs to inform future capital investment decisions and facility upgrade prioritization.[xxvii]	Short-term (2–5 yrs)
PHCs with high flood risk	Raise critical electrical infrastructure (switchboards, panels, generators, solar batteries) to at least 0.5–1m above the known 1:10-year flood inundation level. Relocate electrical equipment from ground level where feasible. Minimum clearance: 0.5 m above assessed 1:100 flood depth	Grey (Engineering)	Commission site-level flood surveys before rehabilitation works. Establish minimum floor elevations for electrical and cold-chain installations in facility design standards. [xxviii]	Immediate (0–2 yrs)
	Construct or rehabilitate site drainage systems: graded surfaces with minimum 1:50 fall to drains, perimeter concrete drainage channels (minimum 300mm × 300mm), soakaway pits (minimum $2m^3$), and connection to existing municipal drainage networks where available	Grey (Engineering)	Include site drainage in all PHC rehabilitation scope of work. Conduct post-construction drainage assessments during first rainy season.[xxix]	Immediate (0–2 yrs)

PLUVIAL FLOODING				
Asset Type	Adaptation Measure	Solution Type	Implementtion - Asset Management	Timeline
	Develop facility-level flood response plans: pre-positioned waterproof storage for medical equipment; pre-identified relocation protocols for cold-chain equipment (e.g., including backup storage contacts within 20km); communication trees for service continuity; pre-agreed alternative service delivery points during facility closure	Grey (Engineering) — Operational	Test plans during dry season drills. Designate a flood response coordinator at each facility. Maintain updated contact lists for backup storage and referral partners	Immediate (0–2 yrs)
	Conduct pluvial and fluvial flood risk mapping at LGA scale to identify high-risk sites, inform future facility siting decisions, and prioritize investment across the PHC network. Commission in partnership with NIHSA and SEMA	Grey (Engineering) — Planning	Engage NIHSA and SEMA in risk mapping. Use outputs to inform future capital investment decisions and facility upgrade prioritization.[xxvii]	Short-term (2–5 yrs)
All Asset Types	Improve access road drainage and surface materials at nearby road connections serving flood-exposed PHCs: concrete box culverts at all watercourse crossings, gravel or laterite road resurfacing at minimum, pavement at priority connections	Grey (Engineering)	Coordinate with state road maintenance authorities. Prioritize roads serving PHCs with high flood hazard ratings. Include in capital improvement programme.[xxvii]	Short-term (2–5 yrs)
	Infiltration / soak-away pits with vegetative enhancement: A hand-dug pit near a downspout or ponding area, backfilled with graded stones/gravel to allow roof runoff to infiltrate, combined with planted vegetation (e.g. grasses, shrubs, or small trees) around and within the pit to enhance infiltration, stabilize soil, and provide evapotranspiration benefits	Green (Nature-Based)	Simple excavation and planting. No machinery needed. Simple clearing of sediment and vegetation required annually (and/or after rain events) [xxx]	Immediate (0–2 yrs)

4.2 Energy resilience-related adaptation options

The availability of a reliable energy source to maintain essential equipment functionality has been identified as a significant issue in the climate risks assessment. Current risks related to the condition or reliability of the energy supply are likely to be aggravated in future climate due to higher extreme heat hazards, but also deteriorating equipment and higher demand. Table 11 presents examples of energy resilience measures that apply to various asset classes.

Table 11. Examples of adaptation measures - energy resilience

ENERGY RESILIENCE (Cross-Cutting)				
Asset Type	**Adaptation Measure**	**Solution Type**	**Implementtion - Asset Management**	**Timeline**
All PHCs (Primary)	Install or upgrade solar PV systems with sufficient battery storage to power cold-chain refrigeration, fans, essential lighting, and communication devices. Minimum specification: 48-hour battery autonomy for cold-chain loads; WHO PQS E003/001-certified refrigerators at all immunizing facilities.	Grey (Engineering)	Conduct energy audits at all PHCs before system sizing. Specify minimum battery backup duration in procurement contracts. Establish performance benchmarks and compliance monitoring. [xxxi]	Immediate (0–2 yrs)
All PHCs (Primary)	Install dedicated solar-powered vaccine refrigerators (WHO PQS certified, Solar Direct Drive preferred) at all PHCs providing immunization services, replacing non-functional or non-compliant units.	Grey (Engineering)	Audit cold-chain equipment at all PHCs. Replace non-functional or non-compliant refrigerators. Include in annual maintenance budget. Assign equipment responsibility to ward-level cold-chain officer.	Immediate (0–2 yrs)
Secondary (Illela GH)	Install a diesel generator with automatic transfer switch as backup to the existing solar system, sufficient to power the entire facility during multi-day clouding or grid failure (e.g., Minimum capacity: 30kVA). Maintain an adequate ~~30-day~~ fuel reserve on site.	Grey (Engineering)	Include generator procurement in facility investment plan. Establish fuel supply protocols including emergency fuel reserve and supplier agreements. Test the automatic transfer switch (ATS) monthly.	Short-term (2–5 yrs)
Tertiary (FNPH)	Expand solar plant capacity and upgrade battery storage to cover all critical areas for minimum 72-hour autonomy. Review generator maintenance protocols and fuel management against projected frequency of grid failures under future climate scenarios.	Grey (Engineering)	Commission energy resilience review. Define critical load schedules. Establish tiered load-shedding protocol for extended grid outages. Document and test ATS quarterly.	Short-term (2–5 yrs)
Supply Chain (Warehouses)	Install continuous temperature and humidity monitoring with automated SMS/email alerts to facility manager and state cold-chain officer; ensure 100% backup power for all cold-storage areas with automatic generator transfer and 72-hour fuel reserve.	Grey (Engineering)	Treat energy and cold-chain systems as Category 1 critical infrastructure. Establish 24/7 monitoring with on-call maintenance capacity. Monthly ATS testing.	Immediate (0–2 yrs)
ENERGY RESILIENCE (Cross-Cutting)				

Asset Type	Adaptation Measure	Solution Type	Implementtion - Asset Management	Timeline
All Asset Types	Establish a state-level energy management information system (EMIS) with real-time visibility of power status across the health facility network — enabling early warning of cold-chain failures and rapid response. Integrate with existing health information system.	Grey (Engineering) — Systemic	Assign responsibility to State Ministry of Health infrastructure unit. Pilot at a representative number of PHCs before state-wide rollout. Integrate with existing health data platforms.	Medium-term (5–15 yrs)

4.3 Asset management and life-cycle considerations

The climate risks assessment demonstrated that poor maintenance amplifies vulnerability even under moderate hazard exposure. Facilities in degraded condition are significantly more likely to experience structural failure, service disruption, and accelerated deterioration under climate stress. Strong asset management (AM) practices are therefore a foundational adaptation measure that underpins all other interventions.[xxxii]

The following are asset management-related recommendations for the Sokoto State healthcare assets.

1. Condition Assessment and Investment Prioritization
   - Conduct structured facility condition assessments across all PHCs, secondary, and tertiary facilities using standardized scorecards covering: structural integrity, energy systems, water, sanitation and hygiene (WASH), cold-chain, drainage, and ventilation.
   - Prioritize investment at facilities with lowest condition scores and highest hazard exposure. Based on the CRA findings, the immediate priority order is: (1) Giran Gero Health Clinic — structural collapse risk; (2) Illah Health Clinic — poor condition + high flood exposure; (3) Tudun Faila PHC — poor-to-fair condition + high flood risk in urban setting.
   - Develop a Facility Condition Index (FCI) for the Sokoto health estate, updated annually, to guide capital and maintenance budget allocation. FCI is calculated as: FCI = Cost of Deferred Maintenance / Current Replacement Value. For example, a target FCI of <0.10 (i.e., deferred maintenance below 10% of replacement value) should be established as a minimum resilience standard.[xxxiii]
2. Maintenance Systems
   - Establish preventive maintenance (PM) schedules for all mechanical systems (fans, generators, solar systems, refrigerators), with defined maintenance tasks, frequencies (monthly, quarterly, annual), and named responsible parties at each facility.
   - Transition from reactive (breakdown) maintenance to planned preventive maintenance (PPM) at all secondary and tertiary facilities within two years. Target: zero unplanned service closures due to preventable mechanical failure by 2030.
   - Formalize Operation & Maintenance (O&M) contracts with qualified local service providers for solar systems and generators, with defined response times (for example, ≤24 hours for critical equipment), performance standards, and penalty clauses.
   - Create a facility maintenance fund at LGA and state levels, with allocation based on asset replacement cost percentages. International best practice target: 2–4% of current replacement value annually. For example, even at 1% for the Sokoto PHC estate, this would significantly reduce the backlog of deferred maintenance.
3. Climate-proofing Design Standards
   - During all rehabilitation works, incorporate climate-resilient design elements as standard: reflective roofing, adequate cross-ventilation, raised electrical infrastructure (for example, minimum 500mm above design flood level), and site drainage.
   - Develop a Retrofitting Guide for Sokoto Healthcare Facilities with specific material and technical specifications for heat and flood adaptation, tailored to local construction practices and supply chains. Include material sourcing guidance to support local suppliers.
   - Ensure no new construction begins without a Climate Site Assessment reviewing: projected pluvial flood risk at the specific GPS location, heat exposure levels under 2050 projections, access road flood vulnerability, and proximity to wildfire-prone vegetation.

4.4 Adaptation options for road disruptions

This section identifies NbS that are particularly relevant for addressing flood-related road disruptions. NbS options were selected at the network level, based on the disruption analysis conducted for four healthcare facilities: Illah Health Clinic, Tundun Faila PHC, Illela General Hospital, and the Federal Neuro-Psychiatric Hospital (FNPH).i

The disruption analysis highlighted critical challenges in maintaining access to care during flood events. In particular, the analysis underscored the need to strengthen referral coordination and transport arrangements to ensure continued access to higher-level healthcare facilities during road disruptions.

NbS are especially relevant in addressing these challenges by reducing flood impacts on road infrastructure. Four NbS options were identified for implementation either at the road level (in proximity to vulnerable road segments) or, for greater effectiveness, at the floodplain level as part of a broader, landscape-based approach:

- Grassed infiltration swales
- Vegetated gabions
- Vegetated terraces
- Vegetated check dams

For each of these NbS, a detailed technical description is provided, including visual illustrations, as well as information on implementation scale and expected timelines.

Grassed infiltration swales

Grassed infiltration swales are shallow, vegetated channels designed to capture, convey, and infiltrate stormwater runoff from adjacent impermeable surfaces such as roads.[xxxiv] Combining elements of traditional swales and infiltration systems, they temporarily store runoff and promote its percolation through engineered soil layers, thereby reducing peak flows.

These systems are typically designed with trapezoidal or parabolic cross-sections and gentle side slopes (generally flatter than 3:1) to ensure stability and facilitate maintenance. Their dimensions depend on expected runoff volumes, rainfall intensity, and available space.[xxxv]

Figure 1. Example of a vegetated infiltration swale located in Australia[xxxvi]

By slowing water flow, enhancing infiltration, and filtering pollutants through soil–plant interactions, vegetated swales effectively reduce flood risks.[xxv] Their capacity to delay and attenuate runoff helps relieve pressure on downstream drainage infrastructure. Studies indicate that they can reduce runoff volumes by approximately 30–50% and peak flows by up to 88%,[xxxvii] depending on site conditions such as soil permeability, vegetation density, and catchment size.[xxxviii]

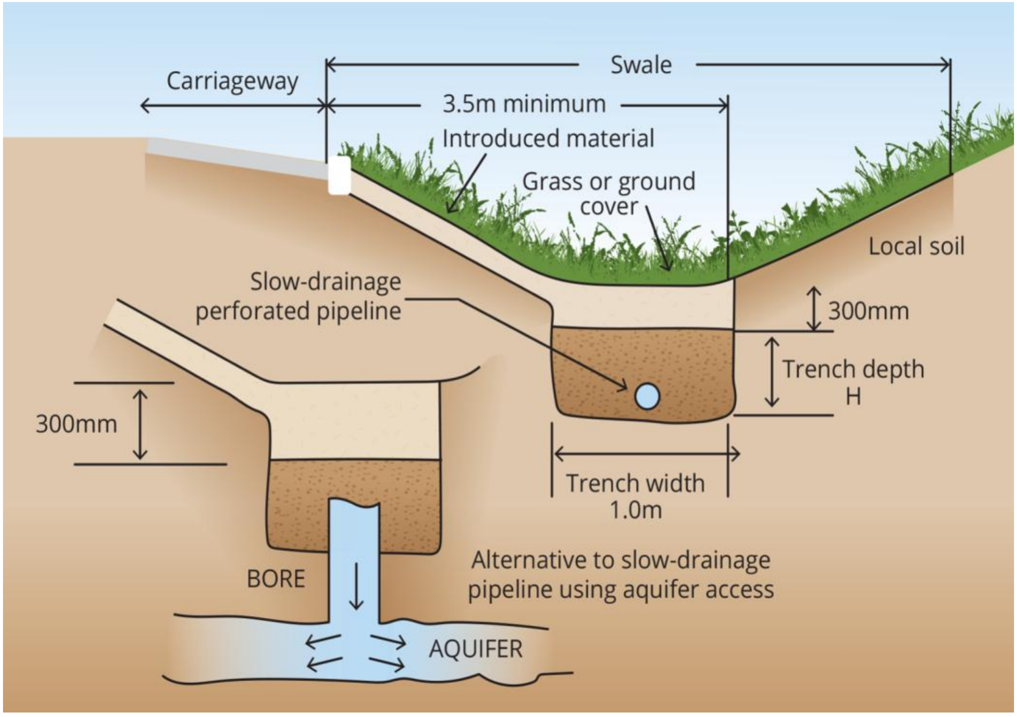
These hydrological benefits make infiltration swales a suitable option for protecting access roads to healthcare facilities, particularly when integrated into a wider stormwater management strategy at the landscape scale in Sokoto State.

Key design and implementation considerations include:

- Core components: a shallow vegetated or stone-lined channel that slows and infiltrates water, supported by permeable soils and vegetation cover; underdrains may be added in low-permeability contexts.
- Hydrological design: site-specific analyses are required to size the swale appropriately, accounting for rainfall patterns, runoff volumes, and seasonal groundwater variations.
- Topography: swales are most effective on gentle slopes. Slopes above ~4% require additional features such as check dams to reduce erosion, while slopes below ~1% may necessitate grading adjustments to prevent waterlogging. Alignment should follow natural drainage pathways.
- Soil conditions: moderately to highly permeable soils (e.g. sandy loam) are ideal. Where soils are less suitable, swales can still function as conveyance systems directing water downstream.
- Vegetation: plant selection should prioritize native, low-maintenance species tolerant to alternating wet and dry conditions, with deep root systems for stabilization and added ecological value.

Swales become operational immediately after construction, but their performance improves significantly as vegetation establishes, typically within 3 to 12 months.

Figure 2. Diagram of main components of vegetated swales[xxxix]



Vegetated gabions

Vegetated stone gabions are proposed for installation along vulnerable sections of the main rivers in Sokoto State, particularly on the outer bends of meanders where bank erosion threatens nearby road networks.These structures consist of rectangular wire mesh baskets (typically made of galvanized steel) filled with stones and integrated with live vegetation.[xl] Their primary function is to stabilize riverbanks, dissipate flow energy, and support ecological restoration.

Figure 3. Gabions on riverbanks in Burundi[xli]

During installation, live cuttings from species such as bamboo or other deep-rooting plants (generally 2–6 cm in diameter) are inserted through the gabion baskets so that they extend into both the stone fill and the underlying soil. This allows vegetation to establish within the structure, reinforcing it over time. Voids between stones can also be filled with soil and seeded to encourage additional plant growth within and around the gabions. Where needed, gabions can be stacked and interlocked to form retaining structures, particularly on steep slopes (typically >1.5:1). [xl]

Gabions provide immediate mechanical stabilization by resisting hydraulic forces and protecting banks from erosion and scouring. By absorbing and deflecting flow energy, they reduce the impact of high-velocity water, especially in exposed river sections. Over time, vegetation further strengthens the system: root networks bind the soil, reduce shallow slope failures, and enhance overall bank resilience. Increased surface roughness from vegetation also slows runoff, promotes sediment deposition, and improves infiltration, contributing to both flood mitigation and ecosystem recovery.[xlii]

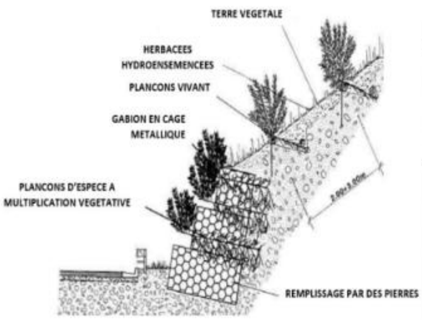
Commonly used for riverbank protection and channel lining, gabions help maintain river morphology while reducing erosion risks, thereby protecting adjacent infrastructure and communities from flood-related damage.[xliii]

Key factors to assess when implementing vegetated gabions are:

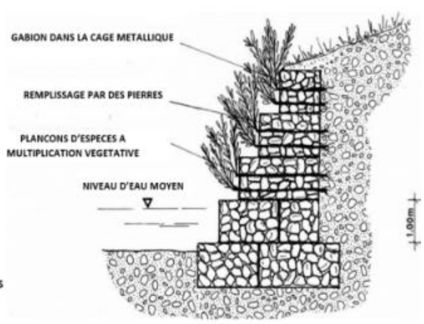
- Structural design: stability must account for geotechnical conditions, hydraulic shear stresses, and appropriate protection of the structure's base and sides (toe and flanks).
- Soil conditions: soils must support both structural anchoring and vegetation growth. In weaker soils, additional measures such as geotextiles or compacted backfill may be required.
- Configuration: gabions should be installed continuously along eroded sections, with a recommended minimum length-to-width ratio of 2:1. Units can be stacked and securely connected to form stable retaining walls.
- Foundation protection: a stone toe or apron is essential to prevent undermining, and structures must be properly anchored, particularly on unstable banks.
- Slope conditions: gabions are most suitable for steep or erosion-prone slopes requiring structural reinforcement. On gentler slopes, lighter vegetative measures may be sufficient.
- Hydraulic context: these systems are particularly effective in high-energy environments (e.g. outer meanders), where flow velocity, flood dynamics, and water level variations must guide design and placement.
- Vegetation integration: where seeding is used, vegetation can be introduced into voids between stones (e.g. ~25 seeds per m^2) to accelerate ecological stabilization.

Vegetated gabions provide both immediate protection and increasing performance over time as vegetation establishes, making them a robust hybrid solution combining engineering and ecological functions.

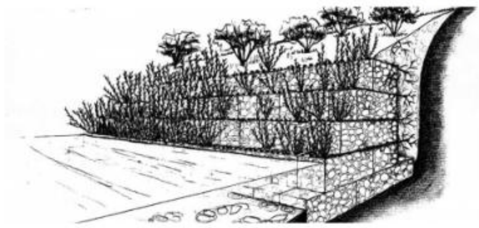
Figure 4. Schematic drawing of gabion systems for slopes and riverbanks[xliv]



Gabions de talus (Sauli et al., 2005)



Gabions de berges (Sauli et al., 2003a)



Gabions de berges (Sauli et al., 2003a)

Vegetated terraces

Vegetated terraces are shallow, linear earth structures designed to slow surface runoff, increase water infiltration, and reduce soil erosion by breaking the continuity of overland flow. They consist of raised and excavated strips arranged along natural contours on which vegetation is planted.

In Sokoto State, vegetated terraces are particularly relevant for flood risk management in road-adjacent floodplain areas, where even modest variations in slope and intense rainfall events can trigger significant runoff and localized flooding. Evidence shows that flooding in the state is driven by multiple factors, with precipitation contributing approximately 34% and slope-related conditions around 30%.xlv This highlights the importance of interventions that simultaneously slow runoff generation and regulate surface flow, making vegetated terraces a well-suited NbS for reducing flood-related road disruptions.

The construction of vegetated terraces involves excavating and compacting shallow platforms aligned with contour lines. Their width and spacing are designed based on local conditions, including slope gradient, soil characteristics, and expected runoff volumes. Where slopes are steeper, terraces are typically narrower and more closely spaced to ensure structural stability and effective control of water movement. Terrace edges are reinforced using vegetation, usually deep-rooted species that enhance soil cohesion and reduce erosion risk. Plants such as Vetiver grass (C*hrysopogon zizanioides*), Bamboo (*Bambusa spp.*), and Acacia (*Acacia spp.*) have been successfully used in stabilization projects due to their rapid growth, strong root systems, and adaptability to tropical environments.

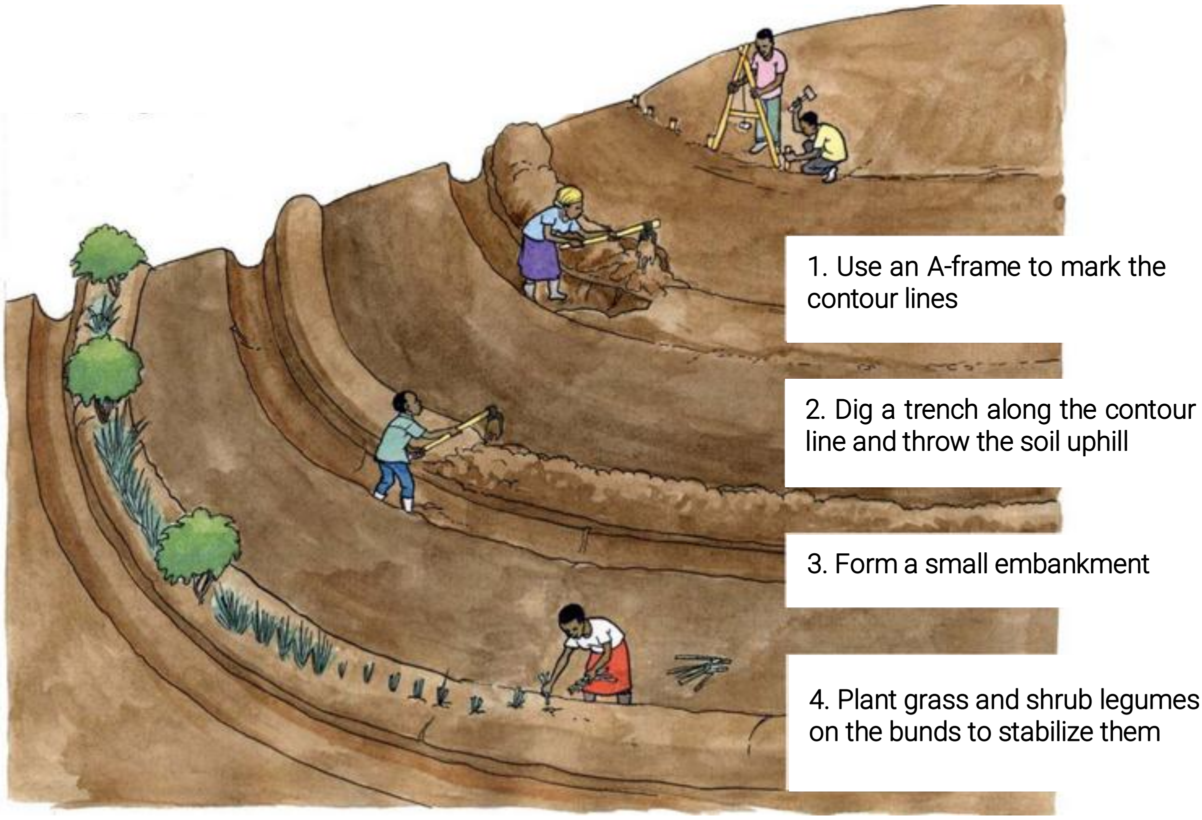
Vegetated terraces reduce runoff velocity by breaking slopes into a sequence of small, horizontal inclined steps. Each step functions as a micro-catchment that retains water, enhances infiltration, and traps sediments. This process improves soil moisture conditions and supports vegetation establishment, particularly in degraded areas prone to erosion or landslides.[xlvi] Empirical evidence shows that terracing combined with vegetation can reduce sediment yield by up to 54% and runoff by approximately 72% in sloped catchments.xlvii These effects translate into improved slope stability, reduced erosion pressure, and enhanced landscape resilience.

Figure 5. Vegetated terraces in Burundi on different types of terrain[xli]

Key aspects to assess during feasibility and design include:

- Site characterization: detailed analysis of topography, soil properties (texture, permeability, stability), and flow pathways. A geotechnical assessment is recommended to identify potential instability risks before implementation.
- Hydrological conditions: evaluation of rainfall patterns, runoff dynamics, seasonal variability, groundwater behavior, and sediment transport pathways to inform design.
- Integration with terrain: terraces should follow natural landforms to minimize earthworks and reduce environmental disturbance.
- Construction timing: implementation is best scheduled during the dry season to reduce risks of erosion, soil compaction, and vegetation stress, with temporary erosion control measures (e.g., mulching, silt barriers) as needed.
- Resource requirements: terracing can be labor-intensive; availability of local materials (soil, vegetation, timber) and skilled labor should be assessed early.
- Environmental impacts: potential habitat disruption and vegetation loss should be minimized through mitigation measures such as replanting schemes, buffer zones, and ecological corridors.
- Community involvement: engagement of local groups or cooperatives is essential for earthworks, planting, and long-term maintenance, while also supporting the selection of locally familiar species (e.g., Vetiver, Bamboo, Acacia).
- Material selection: where temporary stabilization bags are used, biodegradable materials are preferred over plastic to avoid long-term microplastic pollution.

Figure 6. Main stages in the building of vegetated terraces[xlviii]



Vegetated check-dams

Check dams are small, low barriers constructed across gullies and minor drainage channels to control concentrated surface runoff. Their primary function is to slow down flowing water, reduce its erosive force, and retain sediments transported during intense rainfall events. In flood-prone environments, check dams are particularly important where gullies direct runoff toward roads, culverts, and crossings that are frequently damaged or disrupted during heavy rains.

When combined with vegetation, check dams gain additional stability and long-term effectiveness. Plant roots reinforce the structure, strengthen gully banks, and promote gradual regeneration of degraded channels. In the semi-arid environment of Sokoto State, where intense rainfall events often follow long dry periods, this approach is particularly effective for stabilizing gully beds and banks, reducing scouring, and controlling channel enlargement that threatens nearby roads and culverts.

These structures are especially important in areas where gullies convey floodwater directly toward road infrastructure. By trapping sediments upstream, check dams reduce downstream deposition that can block drainage systems and increase flood risk at road crossings. They therefore serve as a key measure for restoring degraded channels, protecting transport corridors, and complementing slope stabilization and land management interventions implemented upslope.

Figure 7. Vegetated check dams in Republic of the Congo[Error! Bookmark not defined.]

Timber for check dams can be locally sourced in Sokoto State, including from sustainable suppliers or suitable materials such as bamboo where available. The spacing of wooden or live check dams depends on gully slope and channel geometry. For effective runoff control and sediment retention, dams are typically installed every 3 to 10 meters along gullies, with closer spacing (3 to 5 m) on steeper slopes and wider spacing (up to 10 m) on gentler gradients. This arrangement improves overall performance by reducing flow momentum and protecting downstream infrastructure, including roads.

4.5 Institutional, operational, and Capacity Measures

Before outlining institutional, operational, and capacity measures, it is important to highlight a critical constraint: the effectiveness of adaptation solutions in Sokoto is highly dependent on a volatile political context. This context is characterized by strong partisan division, which often results in a lack of continuity in public administration. In practice, political transitions may result in important turnover of public servants, which are not always companied with formal handover processes. Moreover, healthcare facilities may be led by politically appointed individuals who may lack the technical capacity or incentives required to perform effectively.

This context has direct implications for the design and sustainability of proposed adaptation measures, particularly those related to capacity building. Training programs, risk management protocols, and emergency response procedures can be developed and implemented, but their impact is often short-lived. Frequent staff turnover, combined with the absence of systematic handovers, means that knowledge and practices are rarely retained over time.

In Sokoto State, the effectiveness of facility-level operational measures therefore depends less on one-off interventions and more on the presence of basic enabling functions at the state and LGA levels. These include clearly defined roles and responsibilities, routine coordination mechanisms, standardized tools and procedures, regular supervision, and reliable activation systems during crises. Given the high turnover of personnel, capacity-building efforts must be embedded in simple, repeatable systems (such as templates, mandatory routines, and accountability mechanisms) that can endure beyond individual staff members and remain functional despite institutional instability.

In consideration of the above, the measures presented in this section focus on non-structural actions at both asset and network levels. They include policy and governance instruments, operational procedures for routine management and emergency response, monitoring and information systems, as well as actions to strengthen coordination, knowledge, and awarenes.

- At the asset level, measures focus on day-to-day operation and maintenance and facility-level response during disruptions.
- At the network level, measures focus on preparedness and coordinated response across facilities and local actors

4.5.1 Asset-level measures

Asset-level measures are presented in Table 12. The measures are organized by the hazard/disruption they address. The table offers information on what is at stake for service continuity and patient safety, the operational solution at facility level, the key implementation barriers likely in Sokoto's rural, resource-constrained context, and practical mitigation actions to reduce those barriers during implementation.

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Table 12. Asset-level institutional, operational, and capactiy measures

Hazard addressed	Stake addressed	Solution	Description of solution	Potential barriers	How to mitigate barriers
Extreme heat	Maintain cold chain and/or detect cold chain breaches	Energy prioritization protocol	Post a one-page priority list at the power point Assign the shift lead to disconnect non-critical loads during outages.	Staff bypass priorities Pressure to power non-critical loads Unclear accountability during outages	Make the protocol visible (wall + duty book) Assign responsibility by role per shift Supervisor spot-checks during hot season
		Manual temperature logging	Record fridge temps in a bound logbook at a frequent time interval predefined in advance	Falsified entries Missing thermometer Staff workload	Use bound book (no loose pages) Attach thermometer inside fridge Simplify recording (green/amber/red) Random supervisor checks against vial monitor/labels.
		Temperature-sensitive labels on critical medicines	Place indicators in the fridge/vaccine carrier; if color changes, trigger transfer protocol	Indicators diverted/sold Misinterpretation Stockouts	Keep indicators under in-charge custody 10-minute practical demo for all shifts Maintain minimum reserve Reconcile indicator counts in monthly review
		Threshold-based vaccine transfer protocol	If fridge temp is outside safe range beyond the threshold: (1) Stop using vaccines and label "HOLD / Do not use". (2) Put vaccines in a cold box with ice packs to stop further warming. (3) Call the pre-agreed receiving facility with working cold chain. (4) Transfer + sign: record time, quantities/batches, and courier, and get receiving signature	No transport Receiving facility refuses/asks "fees" Staff hide the incident No cold box available	Pre-agree receiving point + contacts (and backup) Keep a ready transfer kit (forms + HOLD labels + marker) in cold chain box Use non-cash reciprocity between facilities to avoid fee demands
		Rules to minimize fridge opening and manage electrical loads	Set fixed 'fridge access windows' (e.g., 2 per day). Organize baskets for rapid retrieval; pre-pack carriers during cooler hours; unplug non-critical chargers during outages.	Staff ignore access windows High client volume Poor internal organization	Assign one cold-chain custodian per shift Keep 'ready-to-go' carrier set for peak periods

Hazard addressed	Stake addressed	Solution	Description of solution	Potential barriers	How to mitigate barriers
Any hazards leading to procurement delays	Maintain minimum service levels with critical supplies	Seasonal stockpiling rules before rainy/flood season	4–6 weeks pre-rains, build buffer for high-turn essentials (ORS, antimalarials, antibiotics, delivery kits, gloves, IV fluids). Store on raised pallets; maintain a 'rainy season basket' list.	Diversion/theft Expiry risk Limited storage	Stockpile only essential high-turn items Locked store with two signatories Elevate/waterproof storage Monthly physical count during rainy season.
		Pre-defined minimum buffer stock levels	Define 'never below' quantities for top 10 essentials; when below threshold, trigger reorder note (date-stamped) in reorder register.	Reorders ignored Inflated consumption to mask diversion.	Use threshold trigger + date stamp Cross-check with patient register volumes; Keep reorder copies
		Medication continuity protocol	Maintain a simple continuity list (coded ID, medicine, next due date). Before disruption, provide early refill/bridge supply and plan referral options if stockout.	Missing contact info Diversion Staff turnover	Keep list confidential with coded Ids Keep protocol printed in a 'continuity' folder for new managers
Any hazards leading to patient surges	Maintain safe and continuous essential care during patient surges	Surge protocol (triage + task shifting)	Activate entrance triage; fast-track dehydration/fever; delegate vitals to aides; pause non-urgent admin; designate a runner for supplies and referrals.	Too few staff Resistance to task shifting Informal payments distort triage	Role-based assignments Short refresher drill monthly in hazard season Visible triage criteria poster
		Pre-identified overflow spaces	Identifiy additional pre-assign areas (veranda/shaded outdoor/extra room) for waiting	Space contested Security issues Discomfort in heat Perception of lower quality care	Choose shaded/ventilated spots Communicate overflow is temporary Keep vulnerable groups (pregnant/infants) inside first
Any hazard onset	Fast coordinated response and consistent actions	Internal briefing protocol	At shift start during hazard season: review hazard status, energy plan, stock status, surge roles, referral contacts, and safety notes; record 3 bullets in duty book.	No briefing culture Lateness High turnover	Make briefing automatic at shift change in hazard season Keep script posted
		Facility micro-drills + rapid induction refresh (hazard season)	Monthly 15–20 min micro-drill during hot/rainy season (choose 1 scenario: cold-chain breach, surge triage, or stock disruption). Include a 5-minute refresher for any newly arrived staff on the relevant SOP. Record date + scenario + 3 lessons in the duty book.	Staff time constraints Drills treated as optional Turnover removes trained staff	Keep drills short and linked to shift handover Use one fixed script posted in the duty room Require one simple proof (duty book entry)

4.5.2 Network-level measures

Network-level measures are presented in Table 13 using the same columns as the asset-level table. The "Hazard addressed" column is not included, as all proposed network-level measures relate to flood-related road disruption between facilities.

Table 13. Network-level institutional, operational, and capactiy measures

What is at stake	Solutions	Description of the solutions	Potential barriers	Potential mitigation
Timely access to higher-level care when primary roads are cut	Mapping of critical referral corridors and fallback routes	Before rainy season, prepare a 1-page map/sheet with: (i) critical referral corridors, (ii) known flood cut-points (bridges/low crossings), (iii) 2 fallback routes per corridor, and (iv) referral sequencing rules (where to send patients if route/facility A is unavailable). Keep hard copies at each facility + photo on phones	Route information becomes outdated Staff turnover loses local knowledge Insecurity/roadblocks Sequencing bypassed for 'VIP' cases.	Update annually with drivers/CHWs Date-stamp the sheet Store in facility referral binder + messenger group (e.g., WhatsApp) Record deviations in referral log for accountability
Physical transport remains available for urgent referrals during floods	Pre-agreed transport network	Maintain a roster of external trusted transport options (taxi, 4x4) with call order and backup contacts. Define pickup points and a simple 'release to transport' rule (who authorizes, what form accompanies the patient)	Drivers unavailable Price gouging/informal payments Fuel shortages Vehicles diverted to private jobs	Two-tier roster (primary+backup) Written fee witnessed by community rep Small, documented fuel/airtime contingency trip log tied to referral form before any payment
Referral communication works end-to-end (sending facility, transport, receiving facility) and patients are accepted	Referral coordination protocol (contact list + escalation + capacity status)	Shared contact list (2 numbers per role) and escalation steps (who calls whom, in what order). Use a short call script (patient severity, location, route, ETA). Receiving facilities provide simple capacity status by SMS (GREEN/AMBER/RED) to guide where to send patients.	Phone numbers change calls unanswered Gatekeeping/refusal at receiving facility Unreliable capacity info	Monthly 'ping' to refresh contacts Backup numbers per role Require receiving acknowledgement (SMS 'OK/received') Keep a referral call log district focal mediates repeated refusal

What is at stake	Solutions	Description of the solutions	Potential barriers	Potential mitigation
Receiving facilities are not overwhelmed; referral flows remain functional across the network	Coordination with regional facilities for staggered referrals	Agree overflow rules: if facility A is saturated or cut off, divert to facility B. For non-immediate cases, use agreed staggering criteria (time slots or clinical thresholds). Confirm acceptance by phone before dispatch where possible.	Facilities refuse patients Informal fees Rivalry between facilities Lack of real-time visibility on capacity	Pre-agree acceptance rules at clinical level Maintain refusal log District focal arbitrates disputes quickly Reinforce non-cash reciprocity between facilities
Referral pathways remain functional during flood disruption (routes, communications, acceptance)	Pre-rainy season network drill (route test + call tree test)	Once before rainy season, facilities run a joint drill to test: (1) the call tree (sending → transport → receiving), (2) the alternative route choice for the main corridor, and (3) acceptance confirmation by the receiving facility. Update contact lists/routes immediately after the drill.	Per diem expectations Limited staff time Transport/fuel cost Contacts change after turnover	Make it low-cost Limit to 1 corridor + 1 scenario Attach to a routine district/LGA meeting Require one short after-action note + updated contact list shared to the group

5 MULTI-CRITERIA ANALYSIS AND PRIORITISATION OF ADAPTATION OPTIONS

5.1 Prioritisation Methodology

This chapter presents a high-level analysis of the potential adaptation measures identified in Chapter 4.

The adaptation measures are organized around the following categories: grey (engineering), green (nature-based solutions – NBS), hybrid (grey + green) and soft (policies). A high-level assessment of each measures uses the following indicators:

- Timeline of implementation
    - Immediate: 0 to 2 years
    - Short-term: 2 to 5 years
    - Medium-term: 5 to 15 years
- High-level estimate of adaptation cost (when possible, as a % of the asset/component capital replacement value – CRV)
    - Low: < 10% of CRV
    - Medium: ~ 25%
    - High: > 50% (an asset manager would typically consider that adaptation costs > 50% of the replacement value of a component is high)
- High-level estimate of the effectiveness of the adaptation measure to reduce or eliminate the risk from the climate hazard to the asset or component
    - Low: <10% (high residual risk)
    - Medium: ~ 50%
    - High: >90% (low residual risk)
- Potential barriers to implementation
    - For example, cost, timing, lack of information available, existing controls, existing policies, availability of labor and material, etc.
- Social equity contributions: Impacts on vulnerable groups and overall inclusiveness and whether the local community can contribute in implementing and maintaining the practice.
- Environmental co-benefits: Contributions to biodiversity, emissions reduction, or resource efficiency.
- Institutional feasibility: Alignment with existing policies, availability of institutional capacity, and potential to enhance governance, coordination, and monitoring systems.

Details of the analysis with regards to the criterias mentioned above can be found in Annex 1. The following section provides an overview of the analysis, as well as a prioritized list for implementation of adaptation options based on immediate, short and medium term activites. The schedule only provides a high-level overview; if any of the adaptation measures is considered for investments, it should be evaluated in detail with local data to support the analysis.

5.2 Prioritisation of Adaptation and Resilience Investment Options

Based on the analysis undertaken, Table 14 presents the ranking of measures based on a composite assessment of cost (as a proportion of capital replacement value), effectiveness in reducing climate risk, and estimated benefit–cost ratio (BCR), as derived from the adaptation analysis (Annex 1). Secondary considerations include timeline, social equity, institutional feasibility, and environmental co-benefits. These secondary considerations have been detailed in the adaptation analysis, but are not part of the overview table. Measures with Low cost and High BCR are ranked first; where cost is higher, measures are elevated if their effectiveness is High and the assets protected are critical to health service continuity (e.g., cold-chain, power systems).

Table 14. Ranking of adaptation measures by cost, effectiveness, and benefit–cost ratio

Priority	Adaptation Measure	Climate Hazard	Cost	Effectiveness	BCR	Timeline
1	Shade tree planting around buildings (drought-resistant species: Neem, Afang/Okazi) (all facility types)	Extreme Heat / Heatwaves	Low	High	High	Short-term
2	Bio-based insulating materials (cow-dung plaster/paint on walls, roofs, floors) (all facilties)	Extreme Heat	Low	Medium	High	Immediate
3	Bio-swales and infiltration/soak-away pits for stormwater management (all facilities affected by flooding)	Pluvial Flooding	Low	Medium	High	Immediate
4	Passive cooling elements (cool/reflective roofs, overhangs, cross-ventilation) during rehabilitation (all facilities)	Extreme Heat	Low	Medium	High	Immediate
5	Wildfire season operational guidelines (respiratory medication stocks, referral protocols) (all facilities)	Wildfire	Low	Medium	High	Immediate
6	PM2.5-rated window screens and ventilation filters (all facilities)	Wildfire	Low	Medium	High	Immediate
7	Heatwave response protocols (adjusted hours, staff rotation, hydration, service reduction criteria) (all facilities)	Heatwaves	Low	Medium	High	Immediate
8	Facility-level flood response plans (waterproof storage, cold-chain relocation, communication trees) (all facilities affected by flooding)	Pluvial Flooding	Low	Medium	Medium	Immediate
9	Solar PV upgrade + WHO PQS cold-chain refrigerators at immunizing PHCs	Energy Resilience	Medium–High	High	High	Immediate
10	Raise electrical infrastructure above 1:10-year flood level at high-risk PHCs	Pluvial Flooding	Medium	High	High	Immediate–Short-term
11	Fire suppression systems and perimeter clearance at warehouses	Wildfire	Low–Medium	High	High	Immediate–Short-term
12	Continuous temperature/humidity monitoring + 72-hr backup power at warehouses	Energy Resilience / Extreme Heat	Medium–High	High	High	Immediate

Priority	Adaptation Measure	Climate Hazard	Cost	Effectiveness	BCR	Timeline
13	Shaded outdoor waiting/triage areas (pergolas with climbing vegetation or shade sails) (PHCs)	Heatwaves	Medium	Medium	High	Short-term
14	Ceiling fans and mechanical ventilation in consultation/delivery/waiting rooms (all relevant facilities)	Extreme Heat	Medium	Medium	Medium–High	Short-term
15	LGA-scale pluvial and fluvial flood risk mapping (with NIHSA/SEMA)	Pluvial Flooding	Medium	N/A (planning)	N/A	Short-term
16	Fire-resistant perimeter planting (Neem, Acacia, Moringa) along access roads	Wildfire	Low	High	High	Short-term
17	Site drainage rehabilitation (graded surfaces, perimeter channels, soakaway pits)	Pluvial Flooding	Medium	High	High	Immediate
Note: BCR = Benefit-Cost Ratio. Where BCR is listed as N/A, the measure is a planning/analytical investment whose value is indirect (enabling better targeting of capital). Cost ratings are relative to capital replacement value (CRV) of the component affected.						

5.3 Observations

5.3.1 Overall Adequacy and Breadth of the Proposed Adaptation Measures

The proposed adaptation measures presented in the analysis table above are, based on the data available, as comprehensive and well-calibrated to the climate risk profile of Sokoto State as possible. The measures address the four primary hazard categories identified in the Climate Risk and Vulnerability Assessment — extreme heat, heatwaves, wildfire, and pluvial flooding — with an additional cross-cutting energy resilience strand that underpins the effectiveness of all other measures. The range of solutions spans grey engineering, green nature-based solutions (NbS), hybrid approaches, and operational/institutional measures, reflecting best practice in integrated climate adaptation for low-resource health systems.

A particular feature of the adaptation measures is its layered approach: operational measures (protocols, training) are proposed alongside physical interventions, recognizing that infrastructure alone cannot deliver resilience if staff and systems are not prepared to respond to climate events. This is especially relevant in the Sokoto context, where existing institutional capacity is constrained and many facilities already operate below minimum service readiness thresholds.

5.3.2 Cost-Effectiveness and Nature-Based Solutions

An important finding across the priority analysis is the cost-effectiveness of nature-based and low-technology interventions. Shade tree planting can reduce ambient temperatures by 2–5°C, provide food and medicinal value, support local employment, and improve biodiversity, all with high institutional feasibility and strong cultural acceptance. Similarly, bio-based insulating materials (e.g., cow-dung plaster) and infiltration pits achieve meaningful climate protection at near-zero cost using locally available materials and skills.

This pattern suggests that the first tranche of investments in the Sokoto health system should prioritize the portfolio of Low-cost, High-BCR measures — which are also largely Immediate in their implementation timeline. Many of these can be delivered in parallel with, or even ahead of, infrastructure rehabilitation works, providing immediate risk reduction while longer-lead capital investments are procured and designed.

The NbS measures also demonstrate strong co-benefit profiles: they simultaneously address heat, flooding, fire risk, and community health — compounding their value relative to single-purpose grey interventions. This multi-hazard co-benefit characteristic should be explicitly recognized in investment justifications to funders and government counterparts.

5.3.3 Critical Infrastructure Gaps Requiring Immediate Capital Investment

Despite the high value of low-cost measures, the analysis also identifies a set of higher-cost interventions that should be considered essential for basic health service continuity. Solar PV systems with WHO PQS-certified cold-chain refrigerators and 48-hour battery autonomy represent the most critical capital investment across all immunizing PHCs. Without reliable, climate-resilient energy, cold-chain systems fail during the very heat events that increase vaccine demand, creating a compounding risk that directly undermines immunisation programme outcomes. Similarly, the elevation of electrical infrastructure above flood inundation levels at high-risk sites (Tudun Faila, Illah Health Clinic, Giran Gero) and the emergency structural assessment at Giran Gero Health Clinic are time-sensitive interventions that should be treated as pre-conditions for any rehabilitation investment at these facilities.

Warehouse cold-chain protection — through continuous temperature monitoring, automated alerts, backup power, and N+1 cooling redundancy — is likewise classified as critical infrastructure. The concentration of pharmaceutical and vaccine value in the zonal warehouses means that a single cold-chain failure event could negate the value of multiple field-level interventions. The BCR of these measures is high when assessed against the cost of lost or spoiled commodities.

5.3.4 Implementation Sequencing and Phasing

The implementation framework in the analysis distinguishes between Immediate (0–2 years) critical risk reduction, Short-term (2–5 years) resilience infrastructure investment, and Medium-term (5–15 years) system-level transformation. The Immediate group of measures focuses on the highest-consequence risks: structural safety at Giran Gero, flood protection of electrical systems, energy/cold-chain upgrades, and operational protocols for heatwaves and wildfires.

One key observation is that several of the highest-priority, lowest-cost measures — tree planting, bio-based insulation, soak-away pits, operational protocols — can and should be mobilized in advance of formal procurement cycles. These measures can be implemented through community engagement programs, existing facility management, and low-skill local labor, without requiring formal tendering. Early mobilization of these measures would deliver immediate risk reduction and build community ownership ahead of the larger capital investments.

A further sequencing consideration is the interdependence of measures: flood risk mapping (LGA-scale) should ideally precede final design decisions on electrical infrastructure elevation and drainage at individual sites. Similarly, energy audits should precede solar PV sizing. The programme's inclusion of these planning measures alongside physical interventions is appropriate, but their outputs should be used to dynamically adjust the physical investment programme as data becomes available.

Table 15 presents an indicative implementation schedule for the adaptation measures identified in this chapter; it provides a high-level overview and should be refined through detailed, site-specific analysis using local data prior to investment decisions..

Table 15. Indicative implementation schedule of adaptation measures by timeframe

Timeline	Priority	Key Actions	Asset Types
Immediate (0–2 years)	CRITICAL Address existing risk materializing now	• Emergency structural assessment + rehabilitation (Giran Gero) • Raise electrical systems above flood levels at Tudun Faila, Illah, Giran Gero • Construct site drainage at all high flood-risk PHCs • Solar + WHO PQS cold-chain upgrades at all immunizing PHCs	All PHCs (Primary) Medical Warehouses (existing & new)

Timeline	Priority	Key Actions	Asset Types
		• Heatwave response protocols at all facilities (before dry season 2027) • Warehouse cold-chain backup power and temperature monitoring • Defensible fire buffer zones at all rural PHCs (before next fire season)	
Short-term (2–5 years)	HIGH Invest in resilience infrastructure	• Cool roof and passive cooling retrofits at all PHCs • Generator backup installation at Illela General Hospital • AC expansion to maternity and emergency at secondary level • Bio-swale and vegetated drainage channel installation • Shade tree planting programs at all facility sites • Temperature monitoring network (facility + state dashboard) • Smoke/air quality PM2.5 sensors during wildfire season • Access road drainage improvement at flood-risk PHCs • LGA-level pluvial and fluvial flood risk mapping	All PHCs (Primary) Illela General Hospital (Secondary) Zonal Warehouse (design)
Medium-term (5–15 years)	STRATEGIC System-level transformation	• State energy management information system (EMIS) • Green corridors and urban cooling landscapes at all facilities • Heat-reflective exterior coatings on all existing buildings • Permeable paving and rain gardens at all facility sites • Facility Condition Index (FCI) — full estate annual reporting • State Health Infrastructure Resilience Strategy adopted • Full LGA-scale flood mapping for all 23 LGAs • Air quality monitoring network with NiMet integration	All Asset Types State-level Systems

ANNEX 1 ADAPTATION OPTIONS SPREADSHEET

Attached as a separate document

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