



Adapting immunisation to climate realities: operational challenges and strategic responses

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Cover image credit: Gavi/2024/Quentin Curzon

Cover image caption: “I consider myself lucky to be able to provide these health facilities in this remote area. When I was little, I remember a lot of people falling ill and not even having basic medicines like paracetamol in my remote village. So, right from childhood I always wanted to study paramedics and join the health stream.” – Suresh Kathayat, paramedic at Chhonhup Health Post

Watch the film *Health Heroes of the Himalayas* on VaccinesWork: <https://www.gavi.org/vaccineswork/desert-4000-m-sky-nepals-health-workers-reach-some-worlds-most-remote-communities>

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Introduction

Climate change is one of the most pressing global challenges of the 21st century. Rising global average temperatures, shifting precipitation patterns and extreme weather events are directly impacting human lives and livelihoods, and indirectly undermining the environmental conditions underpinning human health and well-being.

Changing climatic conditions are, for example, associated with the geographical expansion of infectious vector-borne diseases (VBDs)¹ such as [malaria](#), [dengue](#), [yellow fever](#) and [Japanese encephalitis](#), enabling them to spread to areas beyond their traditional geographical scope. Rising flood- and drought-related disasters are also increasing the occurrences of waterborne diseases such as [cholera](#).

More intense and frequent extreme weather events also [directly damage health infrastructures, disrupting access to, and delivery of, essential health services](#) when they are needed the most. Climate change further amplifies the [unique risks and vulnerabilities](#) faced by socially disadvantaged communities, especially [children](#), [women](#) and people living in lower-income countries, disproportionately exposing them to climate-related health impacts.

[Health systems are under growing pressure to respond](#) to climate-induced emergencies, including outbreaks of climate-sensitive diseases and disruptions to the health supply chain. Health workers and emergency responders, especially in outreach programmes in remote and hard-to-reach areas, in turn face [increased exposure to climate hazards and unsustainable demands](#) for healthcare during climate-related health emergencies.

For all these reasons, climate change adaptation strategies need to prioritise strengthening the health resilience of communities, especially by reducing people's risks and vulnerabilities to the health impacts of climate change, as well as ensuring continuity of healthcare services during emergencies, particularly for vulnerable communities.

1. The role of immunisation in climate adaptation

[Immunisation is a cornerstone of climate-resilient health systems](#). It reduces people's vulnerability to many climate-sensitive, vaccine-preventable infectious diseases, and it strengthens preparedness capabilities and response systems during emergencies. When implemented alongside other proven health measures, such as vector control management, early warning systems, and improved water and sanitation, immunisation strengthens the ability of vulnerable and marginalised communities to cope with health risks linked to climate change.

a) Vaccine programmes for climate-sensitive diseases

[More than half of known human infectious diseases](#) are aggravated by climate change (Fig. 1). For those that can be protected by vaccines, routine immunisation and preventive vaccination programmes are critical to reducing morbidity and mortality, especially in areas at high risk of climate-sensitive, infectious disease outbreaks.

¹ For maps of illustrative projected global distribution of key vectors of climate-sensitive diseases, we recommend the following articles:

Malaria – Acosta *et. al.* 2025. *Sci Rep*, **15**:22268, fig. 1.

Dengue, yellow fever – Hu *et. al.* 2025. *BMJ Global Health*; **10**:e014688, fig. 1.

Japanese encephalitis – Tong *et. al.* 2025. *Int. J. Environ. Res. Public Health*, **20**(6), 4701, fig. 6 and 7.

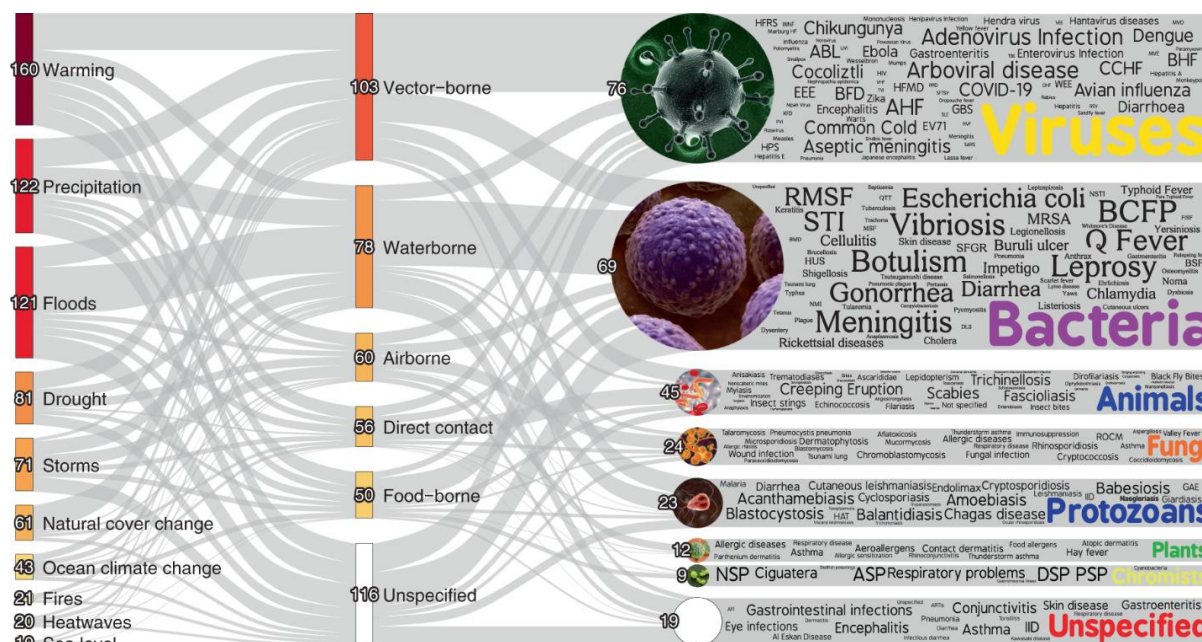


Figure 1. Pathways in which climatic hazards, via specific transmission types, result in the aggravation of specific pathogenic diseases. (Mora et al, 2022)

b) Global vaccine stockpiles

While routine immunisation can build a population's immunity and health resilience during inter-outbreak periods, when outbreaks do strike, an immediate vaccination response is critical to provide the greatest protective impact. [Vaccine stockpiles](#) play a key role in supporting these outbreak response vaccination campaigns rapidly. By setting up stockpiles, health authorities can make sure that vaccines are physically available and ready for rapid shipment and deployment, so that when cases are confirmed, the at-risk population can be protected without delay.

A recent assessment of over 210 outbreaks of yellow fever, cholera, meningococcal meningitis, Ebola and measles in low- and middle-income countries since 2000 concluded that vaccine stockpiles have led to a [60% reduction in cases and deaths](#) from these outbreaks. Alongside surveillance, testing, treatment and communications, vaccine stockpiles can be a crucial part of the response, helping to stop the spread before an outbreak becomes an epidemic or a pandemic.

Gavi, the Vaccine Alliance currently funds [four global vaccine stockpiles](#) (Fig. 2) – for yellow fever, cholera, meningococcal and Ebola vaccines – and is working towards establishing a fifth for mpox vaccines, following approval by the Gavi Board in July 2025. Managed by the International Coordinating Group (ICG) on Vaccine Provision, these physical doses are housed in cold storage rooms around the world and can be accessed by all countries upon the submission of an application based on clear criteria about confirmed cases; or humanitarian contexts, where there may not be confirmed cases yet, but the risks are very high and pre-emptive vaccination is needed to prevent an outbreak.

Examples of vaccine stockpiles funded by Gavi that target climate-sensitive diseases:

Yellow fever: The yellow fever vaccine stockpile is an emergency reserve of 6 million doses kept at the ready to fight epidemics anywhere. As a deployment mechanism, it's designed to move at speed. Countries in need typically receive vaccines a couple of weeks after they make their request to the ICG. The vaccine also works quickly: within ten days of receiving the jab, 80–100% of people will be protected effectively; within one month, 99% of immunised people will be immune for life.

Cholera: The global oral cholera vaccine (OCV) stockpile was established in 2013 and is currently housed outside Seoul, South Korea. Unlike, for example, the yellow fever vaccine stockpile, there is no set size to this emergency reserve, in largest part because the epidemiology of cholera is particularly dynamic. However, recent improvements to production mean that now about 5 million new doses can be made available each month.

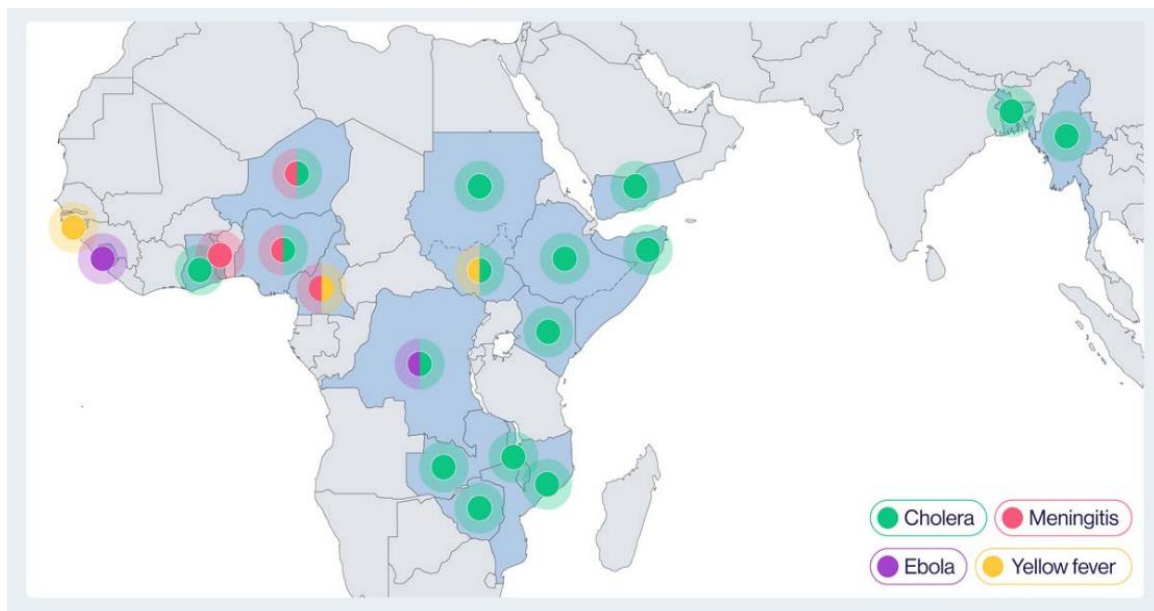


Figure 2. Deployment of Gavi-funded vaccine stockpiles in 2024 ([Gavi, 2025](#))

2. Vaccine and essential health service delivery during climate-related health emergencies

Administering vaccines and ensuring continuity of life-saving health services during and after climate-related health emergencies in affected regions presents a complex array of operational challenges that require forward planning; effective communication and coordination between health service providers, emergency response agencies and local communities; as well as rapid adaptation of healthcare services. Ministries of health must navigate disruptions across the entire vaccine delivery chain, from forecasting and planning, to cold chain management and health workforce mobilisation.

a) Transport and distribution

A key obstacle to the delivery of vaccines and other health services during and after climate-related health emergencies is the interruption to critical logistical infrastructures. Roads, bridges and airports can be rendered inaccessible and inoperable, leaving communities, health facilities and health workers cut off from each other.

To overcome this, governments should invest in climate-sensitive supply chain and procurement planning, contingency routes, and mapping seasonal access patterns. They should also invest in alternative transport methods such as motorcycles, boats and off-road vehicles tailored to local geography, as well as ensure funding for transportation operations and maintenance.

Adapting vaccine planning and procurement in Chad:² To strengthen health system resilience against climate-related disruptions, Chad has implemented proactive planning and procurement measures. Seasonal climate data is now integrated into distribution planning to anticipate risks such as floods and droughts that can hinder supply chains. In addition, safety stocks of health commodities are pre-positioned in high-risk areas to ensure uninterrupted access during emergencies. Delivery schedules are also adapted to seasonal variability, aligning transportation and distribution with periods of accessibility, such as before the onset of the rainy season. These measures aim to maintain continuity of health services and safeguard vulnerable populations during climate and health crises.

Countries are already exploring innovative and diversified transport solutions. In recent years, drone technology, drawing from their successes in delivering vaccines to remote and hard-to-reach areas, has emerged as [a promising tool](#) to navigate obstacles such as flooded terrains for vaccine delivery with unprecedented speed and efficiency. Pilot programmes in several countries have demonstrated the feasibility of drone-based distribution, particularly during emergencies or in mountainous and flood-prone regions, highlighting its potential for broader scale-up.

Vaccines delivered by drones: Gavi has been partnering with Zipline since 2016 to deliver vaccines by drone, expanding health access, especially in areas that are traditionally under-served. By end 2024, more than 21 million vaccine doses were delivered by drone in Rwanda, Ghana, Kenya, Nigeria and Côte d'Ivoire. By leveraging real-time inventory data, GPS coordinates, cold chain requirements and facility-level demand forecasts, Zipline was able to optimise dispatch and coverage. Critically, Zipline's electric drones achieved a CO₂ emissions reduction of up to 98% compared to traditional road transport – saving an estimated 1,800 kg of CO₂ – based on delivery logs, route distances and fuel benchmarks. The dataset included delivery timestamps, vaccine types, quantities, facility identifications, temperature logs and emission estimates, enabling precise monitoring of both health and environmental impact.

b) Local health system preparedness and service continuity during emergencies

Variations in local factors such as geography, availability and quality of critical health infrastructure, human behaviour and cultural practices, as well as policies and regulations, can affect the effectiveness of responses and delivery of health services during climate-related health emergencies.

To account for these local challenges, adaptation interventions against climate-related health emergencies should prioritise locally and community-led preparedness solutions and training of local health workers. This is because local communities know best what they need; and when supported with knowledge, training and material, they are best positioned to design early warning protocols and preparedness interventions that complement national responses to climate-related health emergencies.

By actively engaging local communities, governments can ensure their emergency health services and responses tap into the wealth of knowledge on local risks and expertise, as well as the trusted communication channels utilised by local actors, community-based groups and traditional leaders.

For example, ministries should co-develop with local communities to pre-position safety stock of vaccines in local climate hotspots and adjust delivery schedules to align with seasonal patterns. These measures

² *Impact du changement climatique sur la santé au Tchad. Focus sur les maladies évitables par la vaccination, 15 April 2025.* Directrice de la Lutte contre la Maladie, de la Vaccination et de la Surveillance Épidémiologique (DLMVSE), 2025.

can help ensure continuity of vaccine availability even during adverse weather conditions. Other effective interventions include enhancing emergency health messaging during extreme events and rapid disease-specific emergency responses. In any case, health emergency responses can only be effective when they are well coordinated and planned based on reliable information. Local health systems should therefore regularly stress-test their preparedness systems and ensure their emergency health response workforce is adequately resourced and financed.

AI-powered analytics for improved planning and supply: Gavi's Innovation for Uptake, Scale and Equity in Immunisation (INFUSE) is a platform that helps improve vaccine delivery systems by connecting high-impact, proven innovations with the countries that need them most. It then “infuses” them with capital and expertise to help take them to scale. Causal Foundry, an [INFUSE Pacesetter](#) award-winning partner, is currently working with Gavi to optimise immunisation supply chains using AI-powered analytics and adaptive tools. Their technology helps health workers make better decisions and plan routes more efficiently, improving vaccine delivery to remote communities and reducing missed opportunities. By enabling smarter logistics and resource allocation, Causal Foundry also helps lower the environmental impact of immunisation programmes.

c) Integrated surveillance and climate-informed health early warning systems

Preventing infectious disease outbreaks during and after climate-related health emergencies is a race against time. Not only can extreme weather events disrupt access and delivery of vaccines and other health services by rendering critical logistical, health and communication infrastructure inoperable, the surge in demand for healthcare can also overwhelm the capacity of the local health system to respond.

By providing timely and actionable warnings, early warning systems (EWS) give communities and the health system the critical time to take proactive and preventive measures; prepare for potential impacts; safeguard lives and livelihoods; and protect infrastructure from such hazards ahead of time.

A key step would be to invest in integrating surveillance systems for diseases and weather. This will allow for early detection of resurgence of climate-sensitive, vaccine-preventable diseases; and identification of areas at high risk of disease outbreaks during climate-related health emergencies.

This can, for example, be achieved by [monitoring environmental risks that affect the incidence and distribution of climate-sensitive diseases in conjunction with in-situ and remote-sensing technologies](#) of environmental determinants of health, such as variability of ambient temperature, precipitation, humidity, extreme weather events and water quality.

By monitoring a broad range of environmental signals around a health risk, health officials can identify changing conditions quickly; and anticipate, prepare for and respond to climate-related outbreaks and emergencies.

According to the [Global Commission on Adaptation](#), just 24 hours' warning of a coming storm or heat wave can [reduce the ensuing damage by 30%](#); and spending US\$ 800 million on such systems in developing countries would avoid losses of US\$ 3–16 billion per year.

While many governments have made progress to scale up EWS, [improvements in monitoring and forecasting may be hampered](#) by fragmented disaster risk knowledge, poor data-sharing, underdeveloped technical infrastructure, and weak inter-agency or multisectoral coordination. These challenges make it difficult for health authorities to anticipate disease outbreaks linked to climatic and environmental changes. Moreover, communities are frequently excluded from the design and dissemination of alerts, reducing the effectiveness of emergency health response efforts.

d) From cold chain resilience to health facility resilience

Many medical products, particularly vaccines, are highly sensitive to the ambient temperature and must continually be stored and transported in a temperature-controlled environment. Maintaining the integrity of the cold chain is increasingly difficult in the face of rising temperatures, unpredictable weather patterns and frequent power outages. Many regions rely on outdated or unsuitable refrigeration equipment, which is ill equipped to handle extreme heat. Breaks in the cold chain not only irreversibly compromise vaccine efficacy, but also result in significant dose wastage.

To [strengthen cold chain resilience](#), including against rising ambient temperature and power outages driven by extreme weather events, countries should expand the use of autonomous solar-powered refrigerators as well as solarisation of health facilities, warehouses and storage units, particularly in off-grid areas. Other innovative cold chain solutions include the use of long-term passive devices (LTPD), which apply technologies like vacuum insulation to keep vaccines cold for longer periods before needing to be recharged with icepacks. For example, Arktek is a line of such cold chain devices that can hold up to five litres of vaccines serving around 6,000 people.

Likewise, many digital innovations, such as geospatial mapping and AI-enabled digital supply chain management, have the potential to support climate adaptation of the cold chain. Continuous temperature monitoring through digital loggers can help detect and prevent failures, enabling machine learning algorithms to dynamically adjust the cooling efforts, optimise the energy consumption of the system and keep vaccines viable. Additionally, health workers must be trained in emergency cold chain protocols to respond effectively when disruptions occur.

Health Facility Solar Electrification (HFSE) programme: In 2025, Zambia inaugurated its first solar-powered health facility under Gavi's HFSE initiative. This marks a significant step in expanding access to clean, reliable energy for healthcare delivery in under-served areas.

Building on its **Cold Chain Equipment Optimisation Platform (CCEOP)**, which has already enabled the deployment of over **41,000 solar-powered refrigerators** since 2017 – helping to avert an estimated **15,300 tonnes of CO₂ emissions annually** – Gavi is now scaling up solar electrification efforts.

Through the HFSE programme, Gavi has committed approximately **US\$ 28 million** to electrify more than **1,320 health facilities** across **Zambia, Ethiopia, Pakistan and Uganda**; and an additional **US\$ 11.6 million** for climate-friendly healthcare waste management technologies, in collaboration with **the Global Fund** and **UNICEF**.

By **June 2026**, the project aims to benefit approximately **25 million people**.

In sub-Saharan Africa, where **one in four health facilities lack electricity**, and **two in three have unreliable power**, solarisation ensures continuous care, safe vaccine storage, and improved maternal and emergency services. This initiative not only strengthens health systems, but also enhances **climate resilience** in the face of increasing extreme weather events.

e) Human resources and monitoring

While the broader impacts of climate change on public health are increasingly recognised, the threats that climate change poses to health workers have often remained overlooked. The adverse effects of climate change can [jeopardise the physical and occupational safety, working conditions and mental health](#) of health actors, with cascading impacts to the quality and delivery of essential care. The increased risk of injuries and exposure to climate-sensitive diseases, for example, are known to exacerbate stress and anxiety, particularly during health emergencies and in resource-limited settings. (Fig. 3)

In particular, community health workers (CHWs) play a foundational role to public health, not only because they act as [a bridge between the health system and local communities](#), including for the delivery and

administration of vaccines, but also because they are well positioned to leverage their deep knowledge on the local community and strong ties with families to [increase the uptake of adaptation interventions](#) like vaccination during health emergencies.

To enhance health worker resilience and mitigate these pressures, countries need to provide comprehensive training on climate-related health risks and empower health workers to respond effectively to emerging challenges. These include updating health policies, fostering cross-ministerial coordination, and giving special attention to rural and disaster-affected areas to support health workers facing unique challenges. Establishing mental health programmes will also be key to mitigate the psychological burden on health workers.

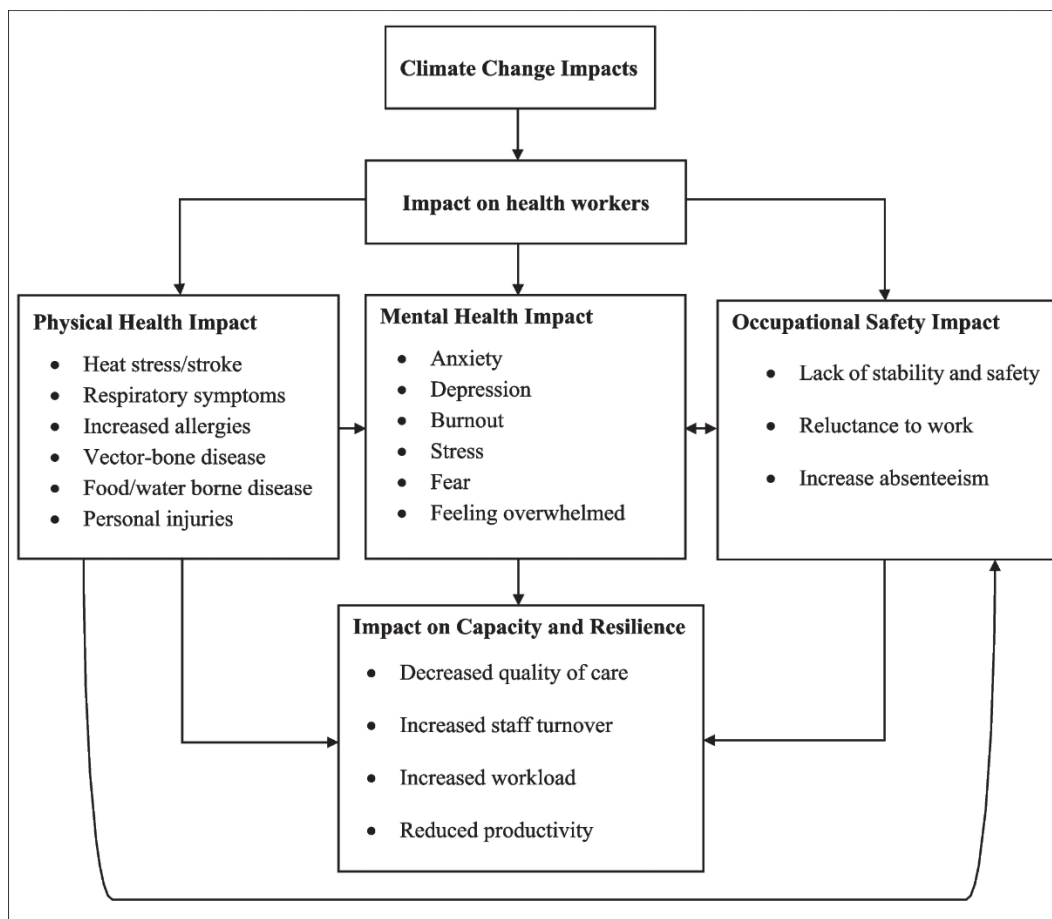


Figure 3. Impacts of climate change on health workers ([Tefaye et. al., 2025](#))

3. Moving to implementation

Building climate-resilient immunisation systems requires more than technical solutions: it demands coordinated action, strategic investment and political will among all stakeholders. Ministries of health are uniquely positioned to lead this transformation in collaboration with other ministries and partners, but success will depend on their ability to integrate climate adaptation into core health planning and delivery mechanisms. As of December 2023, only 43 countries have a Health National Adaptation Plan (HNAP) in place, of which [only 23 were developed since 2020](#), leaving much room for progress.

A first step is to embed immunisation strategies within national climate adaptation frameworks. This includes aligning vaccine programmes with health-focused national adaptation plans and strategies, conducting

Vulnerability and Adaptation (V&A) assessments, as well as ensuring that immunisation priorities are reflected in broader climate and disaster risk-reduction policies.

Investments in sustainable technologies are also critical. The solarisation of the cold chain, health facilities, warehouses and storage units provides access to locally generated clean electricity, thus strengthening the resilience of immunisation and other health programmes to climate-related shocks and disasters, such as heat events or power outages. Additionally, the use of digital monitoring tools and climate-resilient transport solutions can improve service continuity while reducing the environmental footprint of immunisation programmes.

Finally, global collaboration remains essential. Countries must work closely with international partners to secure access to emergency vaccine stockpiles, share best practices and mobilise funding for climate-resilient health infrastructure. Regional cooperation can also help harmonise standards and facilitate cross-border responses to climate-sensitive disease outbreaks.

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