Future-proofing sanitation services

A climate-resilience capability framework for utilities

1st Edition: Co-creating the framework with stakeholders

About this report

Providing water or sanitation is a necessary operational capability for utilities, but it is not sufficient. Additionally, utilities need the capability to identify and anticipate factors that could disrupt or enhance service provision, capture opportunities, and avoid threats, and embed identification and capturing processes and routines into their workflows. Such factors are dynamic and include climate change impacts, new mandates introduced by policies, and funding shortfalls, among others. The latter capability, referred to as dynamic capabilities, is strategic and dynamic and has the potential to improve operational capabilities in utilities, thereby leading to more self-aware, adaptive, innovative, and transformative utilities. Such utilities can extend and improve the resilience of services in evolving contexts.

This report documents the early development stages of a framework that demonstrates how dynamic capabilities can shape operational capabilities to deliver better non-sewered services, considering climate change impacts from a utility's perspective. It is a product of multiple stakeholders and part of ongoing work on utility capabilities.

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Foreword: Regulatory imperatives for climate-resilient non-sewered sanitation in Kenya

As in many countries, sanitation regulation in Kenya has been designed around centralized, sewer-based systems, with the Water Services Regulatory Board (WASREB) previously focusing on compliance, enforcement, and infrastructure expansion. However, climate change and rapid urbanization have exposed the limitations of this approach, particularly in contexts where non-sewered sanitation (NSS) systems are the only feasible and affordable options for most of the population. Thus, regulation is evolving from the traditional technical oversight to a more adaptive and enabling function that actively supports climate resilience.

WASREB has recognized NSS as a permanent, legitimate, and critical service rather than a temporary or inferior solution. This shift has facilitated the development of flexible standards that consider diverse technologies, settlement patterns, and climate vulnerabilities, including flooding, drought, and groundwater stress. NSS systems are critical for achieving safely managed sanitation but face increasing risks from climate change. Therefore, instead of prescribing one-size-fits-all designs, regulation now emphasizes performance outcomes—such as containment integrity, safe wastewater management, and environmental protection under extreme weather conditions.

WASREB is increasingly enabling innovation by approving climate-resilient technologies, supporting decentralized treatment options, and integrating sanitation planning with climate adaptation and disaster risk management through its licensing and tariff-determination regimes.

This evolving role positions regulation as a bridge between policy, financing, and implementation. It is anticipated that aligning regulatory requirements with national climate commitments and adaptation strategies will unlock climate finance for NSS improvements, incentivize investments in resilient infrastructure, and protect vulnerable populations. This will ensure that sanitation regulation moves beyond control and compliance to become a strategic enabler of climate resilience, public health protection, and sustainable service delivery in a changing climate.

In collaboration with strategic partners, WASREB is strengthening the capacity of Water Service Providers and County Governments to plan, design, and manage climate-resilient non-sewered sanitation systems. Through these partnerships, efforts are focused on enhancing risk-informed data collection to identify climate-vulnerable areas and on linking NSS investments to climate adaptation and resilience financing. By leveraging the complementary roles of regulators, service providers, counties, and development partners, these initiatives collectively safeguard public health, protect water resources, and support Kenya's broader sustainable development and climate commitments.

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This report serves as a starting point for further engagement in developing strategic oriented capabilities for water and sanitation utilities and other complementary organizations by the Organization and Climate (O&C) research group at the Department Sanitation, Water and Solid Waste for Development (Sandec) of the Swiss Federal Institute of Aquatic Science and Technology (Eawag), in collaboration with policy and practice, research, and funding partners. The group welcomes further collaborations to develop this topic over the long term.

The report is an output of the PREF4WASH (Practice,

Research and Funding for Water, Sanitation and Hygiene) initiative. PREF4WASH is a global community of practice organized by the O&C group at Sandec. It leverages science communication for the enhancement, uptake, and use of scientific knowledge related water, sanitation, and hygiene services among stakeholders. The community promotes research collaborations that connect researchers, practitioners, and funders to deliver timely solutions to water, sanitation, and hygiene challenges.

In Kenya, the PREF4WASH-Kenya community brings together water utilities, the private sector, universities, government agencies, and civil society organizations to produce timely research that benefits all parties and delivers necessary solutions in the water and sanitation sector. The community's activities are currently led by the Nakuru Water and Sanitation Services Company (NAWASSCO), Water and Sanitation for the Urban Population (WSUP) and Meru University of Science and Technology and involve close collaboration with other universities and the Water Sector Trust Fund, with coordination support from Sandec. PREF4WASH-Kenya, in partnership with the Water Services Regulatory Board (WASREB) and other partners, facilitated the development of this report.

Executive summary

Urban sanitation in Kenya—and across many African contexts—relies heavily on non-sewered sanitation systems, including pit latrines, holding tanks, septic tanks, emptying services, wastewater treatment, and resource recovery facilities. These systems serve approximately 85% of Kenya's population, as only 15% of Kenyans are connected to sewer systems. The non-sewered systems are increasingly vulnerable to climate change, including flooding, drought, and extreme weather events, which threaten infrastructure, service continuity, and public health. Addressing these challenges requires utilities to develop both operational and strategic (dynamic) capabilities to manage, adapt, and transform sanitation services, thereby building resilience to disruptions. This is especially critical, given that utilities are increasingly shifting from purely centralized infrastructure to "citywide inclusive sanitation." By integrating and overseeing managed non-sewered systems, they aim to achieve universal access, lower capital costs, and increase climate resilience.

This report presents the Climate Capabilities Framework, a work in progress, to enhance strategic (also known as dynamic) capabilities within utilities, with a focus on improving resilience to climate change impacts on non-sewered sanitation services. Dynamic capabilities entail the utility's ability to know when and how to adjust its operations in the presence of imminent risks (threats or opportunities). The framework is a work in progress and was co-created through a participatory process involving utility operators, regulators, funders, researchers, and development partners. Using the dynamic capabilities approach elaborated in Chapter 3, participants non-exhaustively mapped climate risks and opportunities across the sanitation service chain, prioritized critical challenges, and identified the capabilities required for utilities to respond proactively to each risk and opportunity to ensure service extension and resilience. These co-produced insights were synthesized to inform the Climate Capabilities Framework presented.

The Climate Capabilities Framework provides a systematic and dynamic approach to assessing and implementing the necessary interventions to develop strategic capabilities within utilities' sanitation chains. These include identifying and specifying risks and opportunities posed by climate impacts in advance (sensing capabilities), capturing opportunities and avoiding threats by the utility (seizing capabilities), and using insights gained to reconfigure how the utility handles such threats or opportunities in the future (transforming capabilities) across the sanitation chain.

The Climate Capabilities Framework links strategic capabilities directly to the sanitation chain's operations—from user interface and containment to treatment, reuse, and disposal—while exploring how to anticipate and mitigate climate-related disruptions and leverage emerging opportunities at the utility management level. While it requires further development, the framework provides a promising, utility-centered roadmap for achieving sustainable, safe, and inclusive sanitation services amid climate change. It contributes to broader knowledge and action for resilient urban sanitation globally and complements other tools and concepts, such as Citywide Inclusive Sanitation and the World Bank's Utility of the Future.

Practical use cases for utility managers, consultants, funders, regulators, and researchers are provided here primarily for experimental purposes. Suggestions for their engagement with the Climate Capabilities Framework are also included to guide the way forward.

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1. Background

Many urban areas in Africa rely on non-sewered sanitation, and Kenya is no different. The country's sanitation landscape is primarily composed of non-sewered systems, including pit latrines, septic tanks, emptying trucks, and wastewater treatment and resource recovery facilities. These systems serve approximately 85% of the population (WASREB, 2025). The systems are often depicted as a chain ranging from the user interface (toilet) to containment (pits, holding tanks, septic tanks, among others) for storage, emptying, and transport; treatment; resource recovery; and disposal. These collectively provide sanitation services. This situation is similar in many other countries since nearly half of the global population uses non-sewered sanitation (Odagiri et al., 2021; Strande, 2024).

Non-sewered sanitation systems are increasingly vulnerable to climate change, particularly to extreme weather events such as floods and droughts. Flooding in containment areas contaminates water sources and damages infrastructure, whereas droughts can concentrate waste, complicate emptying, and disrupt treatment processes (Hyde-Smith et al., 2022). Given these vulnerabilities, climate resilience must be built into water and sanitation systems to ensure uninterrupted service. Climate resilience is the capacity to anticipate, respond to, cope with, recover from, adapt to, or transform based on climate-related events, trends, and disturbances, all while striving to achieve and maintain universal and equitable access to safely managed services, even in the face of an unstable and uncertain climate (SWA, 2024).

Traditionally, water and sanitation utilities have focused on large-scale, centralized infrastructure such as extensive sewer networks and centralized wastewater treatment plants. Non-sewered sanitation (e.g., septic tanks, on-site treatment) was relegated to individual household responsibility, private contractors, or informal management (Van Welie et al., 2019). However, utilities are increasingly adopting a "citywide inclusive sanitation" approach, recognizing that integrating non-sewered systems, such as community-scale anaerobic systems or cluster-based wastewater treatment systems, is necessary for achieving universal, sustainable access (Khaki et al., 2026). This shift is driven by the need to increase resilience to climate change and infrastructure failures, reduce the massive capital costs of pipe networks, and enable local water/nutrient reuse. Modern utilities are expanding their roles by managing, inspecting, and maintaining these non-sewered systems, acting as overseers of distributed infrastructure to ensure high-quality, regulated service. This trend is observed across many countries, including Kenya, Uganda, and Zambia. In Kenya, the shift toward non-sewered sanitation (NSS) reached a critical milestone in 2019 through the development of the Water Services Regulations and the National Sanitation Management Policy. This mandate operationalizes the Water Act of 2016, which transferred responsibility for sanitation services to county governments and their licensed Water Service Providers. Many other utilities globally are, or will need to, handle sanitation services, particularly in urban settings where climate impacts and urban sprawl are evident. This new role requires developing capabilities at the utility level.

Global awareness of climate risks has created opportunities to act, including new partnerships and funding sources for sector stakeholders. Despite these efforts, the capabilities to anticipate, leverage opportunities, and mitigate risks in the sanitation sector remain nascent and require urgent enhancement. Enhancing them requires ongoing research, strategic management, and flexible regulation to enable utility transformation from mere reaction to strategic anticipation. Capabilities are the collective abilities of an organization to perform coordinated tasks, leveraging its resources and knowledge to achieve strategic goals. They constitute a unique combination of skills, processes, technologies, routines, and employee expertise that enable an organization to execute its strategy, adapt to change, and deliver value to customers.

Capabilities differ from capacity in that capacity is the maximum amount, e.g., the number of residents that a utility can serve or the amount of wastewater a utility can treat. It measures volume, throughput, or bandwidth and only answers the question: "How much can we do, or how fast?" **Capabilities,** on the other hand, refer to the ability or power to perform an action. It is the collection of features, skills, resources, and expertise that enable an outcome and answer the question: "Are we able to do this?" Capacity is therefore the amount a utility has, while capability is how it uses what it has.

Capabilities are grouped into two categories in scientific literature:

- **Dynamic capabilities.** These are the utility's abilities to know when and how to adjust its operations in the presence of imminent risks or opportunities and are strategic in nature (Teece et al., 1997). Examples of strategic capabilities include innovation, adaptability, partnership management, opportunity and risk scanning, among others.
- **Operational capabilities.** These are the utility's abilities to perform its day-to-day operations as expected by its customers. Examples include emptying toilets, constructing toilets and containment infrastructure, and treating wastewater and recovering resources.

To improve capabilities in utilities, this report synthesizes insights from stakeholder engagements to co-develop a Climate Capabilities Framework for the nexus of non-sewered sanitation and climate impacts. The framework is a starting point for clarifying the capabilities utilities need to enhance climate resilience. The framework, while derived based on insights from Kenyan stakeholders, is also relevant regionally and, to some extent, globally. Ultimately, the framework aims to contribute to the shift from what needs to be done to how it can be done; specifically, it identifies and enacts the capabilities within utilities necessary to achieve climate resilience, contributing to global efforts for universal sanitation services. The framework further contributes to knowledge and action for climate-resilient sanitation beyond infrastructure, positioning utilities as agents of change rather than victims of their circumstances.

2. Foundations of the Climate Capabilities Framework

The framework focuses on utilities as the main service providers, supported by other external organizational forms and stakeholders, including regulators, social enterprises, civil society organizations, and sub-national and national government departments such as those for urban planning. It builds on current knowledge of the sanitation chain's operational capabilities and introduces dynamic (strategic) capabilities necessary to enhance them.

Importance of focusing on Utilities

Utilities are the primary interface for the provision and access of sanitation services for users. They manage the delivery of sanitation services and maintain critical infrastructure for treatment and resource recovery. They are uniquely positioned to influence service quality, investment, efficiency, and catalyze resilience because they control operations, resources, and human capital, and are mandated by national and subnational governments to provide services within their coverage areas. Focusing on utilities ensures that interventions target the mandated stakeholders who provide the required technical capacity to implement system-wide changes (UN Habitat, 2025). The framework can nonetheless be adapted to different organizational scales, such as households and social enterprises, as well as to sub-units, such as departments within an organization.

In the face of climate change, utilities face heightened risks, including flooding, extreme rainfall, water scarcity, and infrastructure strain across their service areas. Strengthening utilities' dynamic and operational capabilities ensures they are better equipped to anticipate, absorb, and respond to these shocks not only through infrastructure and technology but also in their organizational structures, routines, processes, and culture. A utility-centered approach ensures that climate resilience is not an abstract policy goal, but a practical, operational reality embedded within the organization responsible for continuous service delivery. Beyond climate, strengthening utilities also gives them the agency to navigate their stakeholder ecosystem and contexts. For example, capable utilities can steer collaborations with urban planning and other departments, advocate for more feasible regulations, and engage partners productively, spearhead new markets for resource recovery products, among other abilities, as observed in light house cases in places like Hamburg, Nakuru, and Melbourne (Binz et al., 2024).

Interests and operational capabilities of the utility along the sanitation service chain

The sanitation service chain, though highly infrastructure-focused, offers a useful view of all stages required for safe, reliable sanitation, from waste generation to final disposal or reuse. It can either be sewered or non-sewered. The non-sewered is illustrated in Figure 1, mainly comprising the following components, but may look different if treatment occurs onsite:

a. **User interface:** This is the type of toilet, pedestal, pan, or urinal by which the user accesses the sanitation system (e.g., pour flush toilets, flush toilets, dry toilets, urine diverting toilets, etc). This is usually part of the larger toilet superstructure.

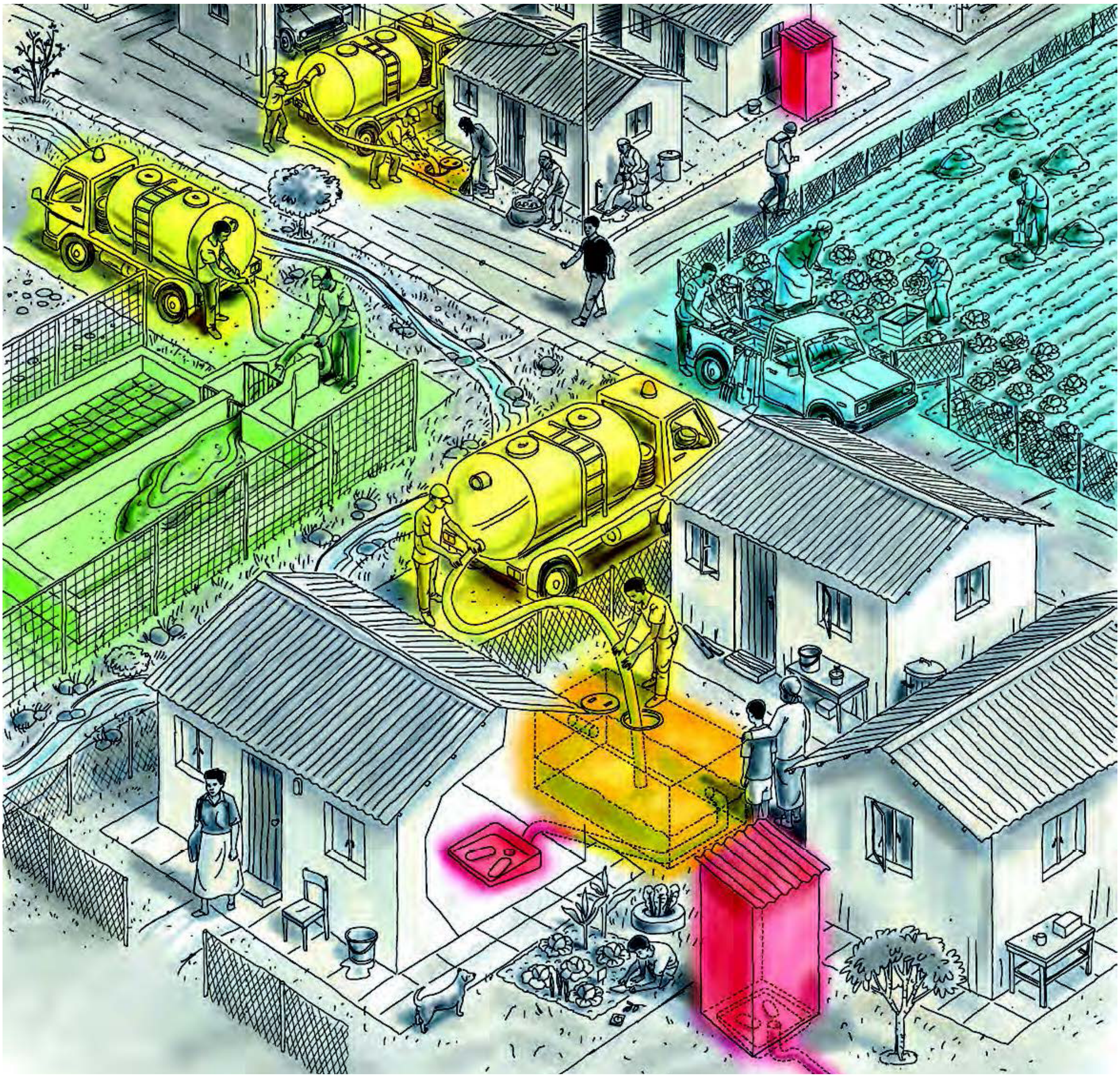
b. **Containment:** Safe capture of human waste at the household or community level (e.g., septic tanks, pits, holding tanks, etc).

c. **Emptying:** Timely removal of waste from containment systems to prevent overflow that could lead to environmental contamination or public health risks.

d. **Transport:** Safe movement of waste to treatment facilities through trucks or other conveyance methods.

e. **Treatment:** Processing waste to neutralize pathogens to manage environmental and public health risks.

f. **Disposal, re-use or resource recovery:** Safe disposal in the environment or resource recovery as energy, fertilizer, or other resources.



Interface	Containment	Emptying & transport	Treatment	Reuse	Disposal
Pour flush, flush, dry toilets	Pits, septic tanks, container based	Manual, mechanized, water based	Waste stabilization ponds, imhoff tanks, anaerobic batch reactors etc	Fertilizer, briquettes, nutrient recovery biogas, irrigation	To water bodies, land fills

Figure 1: The typical sanitation service chain.
Source: modified from Eawag's sanitation Compendium (Tilley et al., 2014)

Utilities that actively manage non-sewered sanitation are interested in safe removal of wastewater from the communities they serve, as well as high-quality wastewater in sufficient quantities, primarily for resource-recovery products such as briquettes and compost. At the operational level, their primary responsibility is to collect, treat, and/or recover resources, either directly or through subsidiaries. Therefore, the utility needs capabilities to handle operations that ensure high-quality wastewater is delivered from households and other sources for treatment and resource recovery, as illustrated in Table 1. High-quality wastewater ideally contains minimal foreign materials, such as solid waste.

Mechanical and manual emptiers transport wastewater to the treatment and resource recovery centres. The utility's interest at this point is to maximize wastewater delivered by ensuring none is disposed of elsewhere than designated discharge points. The essential operational capability is overseeing emptying and logistic operations of emptying trucks – an activity largely conducted by private operators and partly by some utilities - as well as the quality and quantity of the contents and the containment source from emptying to discharge. Protecting sanitation workers during collection operations is another responsibility of utilities, as they face significant risks, including exposure to toxic gases, infectious diseases, and physical injury. In addition, developing and managing partnerships with complementary stakeholders in this space is required. The utility also has an interest in ensuring that its coverage area has toilets with functional interfaces. While it may not be their primary mandate to construct facilities, utilities have an interest in encouraging households within their jurisdiction to construct toilet facilities. They need the capability to achieve this to uphold standards that promote safe sanitation.

When wastewater is delivered to treatment plants and resource recovery centres, these centres produce products such as compost, biogas, and briquettes, as well as reusable water if the supernatant is adequately treated. These are intended for sale, reuse (e.g., biogas for electricity generation to power treatment plants), or safe disposal. Utilities, therefore, require business operations capabilities such as market assessments, logistics, and customer management, among others, while adhering to effluent standards. Where utilities' roles are secondary, they must rely on partnerships and collaborations with other stakeholders in their ecosystem. For instance, construction works for toilets are approved at different government departments, such as urban planning, requiring utilities to coordinate with these departments to ensure sanitation facilities are sited and constructed appropriately. In addition, emptying services are often provided by the private sector, rendering the utility as the overseer and licensor of the exhaust truck services. Utilities are often regulated to ensure effluent quality and fair tariffs; therefore, they must maintain good relations with the regulator. Therefore, while utilities are an important focus, other stakeholders also play a major role in delivering sanitation services.

All the capabilities discussed in this section are essential and focus on doing the right things to ensure the successful management of pathogens and the recovery of resources. However, they are insufficient, especially when external factors, such as extreme climate events, disrupt operations. For example, when extreme rainfall floods the wastewater treatment plant.

Sanitation service chain

	Utility's interests	The utility's responsibility	Utility's expected operational capabilities
Interface	Acceptable toilets that encourage use Proper actual use of toilets to ensure high-quality wastewater	Secondary	Monitoring toilet use Advocating for toilet construction and proper use practices
Containment	Well-designed containments that contain all the wastewater without external interference	Secondary	Monitoring structural quality, locations, and capacities of existing containments Advocating for engineered designs and proper siting of containments
Emptying and Transport	Well-sited containments that eliminate public health risks, and that allow access during emptying Transported wastewater ends up in the designated discharge points Sanitation workers are protected from toxic gas exposure, diseases, and physical injury	Primary or secondary	Controlling proper siting through plan approvals Monitoring and or conducting emptying and transport – the logistics, including sanitation safety planning Monitoring wastewater quality Pricing the service
Treatment	Efficient and effective treatment process	Primary	Treating delivered wastewater from non-sewered sanitation systems Monitoring the efficiency of the treatment process
Reuse and Resource Recovery	Efficient resource recovery processes Potential market for recovered products	Primary or secondary	Advocating/facilitating/enabling for resource recovery Manufacturing recovery products, such as compost, nutrients, biogas, water for reuse, among others Marketing and selling the products
Disposal	Adhering to established standards for effluent and disposal of other byproducts	Primary	Monitoring and compliance with effluent quality standards

Table 1: Operational capabilities for non-sewered sanitation based on utility's interests and level of responsibility

Potential impacts of climate change on the sanitation chain

Climate change effects include prolonged or more intense precipitation, which increases the risk of flooding, erosion, and landslides, as well as contamination and damage to water supplies. They can also include more variable or declining rainfall or runoff, and, when coupled with rising temperatures or heatwaves, can lead to extreme droughts. Furthermore, effects such as sea level rise can lead to rising groundwater levels and saline intrusion in coastal areas (Hyde-Smith et al., 2022). These effects affect sanitation services by damaging infrastructure, disrupting operations, or interfering with the performance of processes, such as treatment and resource recovery. Such an impact renders operational capabilities unable to guarantee uninterrupted service provision.

Flooding can overwhelm containment infrastructure, rendering it unusable; disrupt emptying activities; block transport routes; overwhelm treatment plants; and disrupt resource recovery processes. Drought and rising temperatures can increase pollutant concentrations in wastewater, increase the risk of corrosion, reduce the risk of groundwater pollution, and alter the efficiency of biological treatment processes. Though less discussed, climate-related disruptions and subsequent adaptation measures on the sanitation chain also offer opportunities to support development of enhanced regulation, capacity strengthening, investment, and partnerships to ensure sanitation services remain resilient, safe, and equitable.

Avoiding risks and taking advantage of opportunities, in turn, requires nurturing capabilities in utilities beyond operations. These additional capabilities are referred to as dynamic capabilities in the scientific literature. They inform strategic decisions through organizational awareness, adaptation, innovation, and transformation amid changing internal or external dynamics within a utility (Teece et al., 1997).

Dynamic capabilities in organizations

Dynamic capabilities inform which, when, why, how, and whether a utility's operational capabilities should change in response to external influences or internal needs. In other words, which operations to update, which ones to adapt, and when. Changes are triggered by either the need to avoid potential negative risks or capture opportunities. Dynamic capabilities focus on doing the right things at the right time. The impacts of climate change explored earlier present both risks and opportunities for utilities. Dynamic capabilities, therefore, serve the following three functions at the utility level:

a. Ensure readiness by **sensing** the risks and opportunities

b. Promote innovation and adaptation by proactively identifying opportunities to **seize** and risks to avoid

c. Lay the foundation for overall utility **transformation** based on insights from sensing and seizing by reconfiguring existing processes, structures, and culture.

Sensing, seizing, and transforming functions are therefore the core categories of dynamic capabilities.

In the context of non-sewered sanitation, **sensing capabilities** are critical for utilities to navigate the complex landscape of public health needs, technological innovation, regulatory shifts, user preferences, and climate change impacts. This involves systematically screening for opportunities, such as pit-emptying or on-site treatment technologies, and for risks, such as funding gaps or user-acceptance barriers. It requires recognizing internal technical and social expertise valuable for new service models, actively networking with communities, governments, and global stakeholders to understand local needs, and institutionalizing idea generation to foster innovative solutions for safe sanitation access.

Utilities that are poor at sensing have limited awareness of the resources they need – quantity, quality, processes, partners, context advantage, and technologies – to improve their operations. They basically fly blind due to uninformed strategies.

Seizing capabilities enables utilities to act on the insights they sense, for example, by building viable and adaptable business models for sanitation services with relevant partners, defining clear strategies for new service entry or scale, and structuring agile decision-making to secure funding and partnerships, among other resources. This often involves acquiring and leveraging new resources—a key activity—to deploy sanitation systems, entering new geographic or demographic markets, and forming service partnerships with municipalities, other actors, or technology firms to close critical resource gaps. Furthermore, proactively shaping ecosystems by advocating for supportive policies or creating new market standards is essential for sustainable service delivery.

Utilities that are poor at seizing opportunities struggle to mobilize resources to capitalize on sensed opportunities that could enhance operations or to acquire external resources. They are therefore less adaptive and less innovative and are stuck with information overload from seizing activities.

Finally, long-term success in non-sewered sanitation will depend on **transforming capabilities** that reconfigure the utility. This entails continuously acquiring and disseminating knowledge about technical performance and user behaviour, reconfiguring internal teams and external partner networks to improve service integration, and discarding outdated operational approaches. Transforming requires restructuring the organization to balance innovation and adaptation with routine service delivery, and to foster a culture informed by community needs. Genuine top-management commitment is vital to drive this comprehensive change toward sustainable and scalable sanitation solutions. All in all, transforming capabilities institutionalize sensing and seizing capabilities that have proven effective within the organization and beyond.

Utilities that are poor at transforming find it challenging to reconfigure resources and the organization itself in response to new insights from sensing and seizing. They are unlikely to lead to any sectoral transitions since they are either stuck at seizing which translates to many pilots that barely scale.

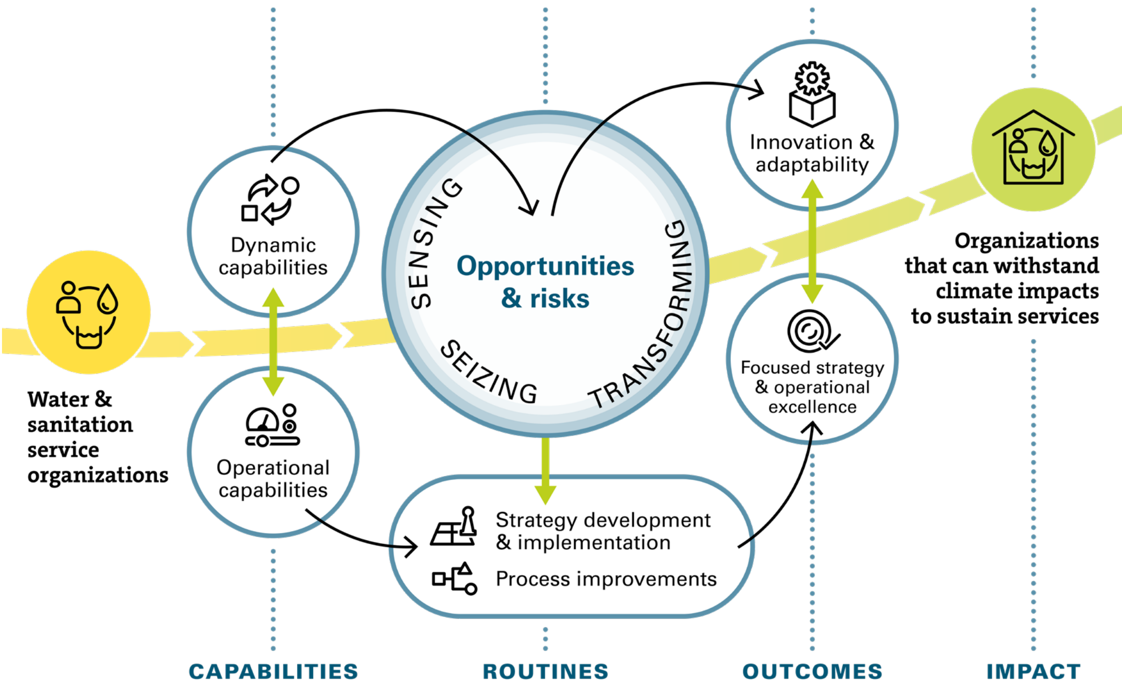


Figure 2: The interplay of dynamic and operational capabilities in a typical water or sanitation organization. Source: Eawag

3. The Climate Capability Framework for non-sewered sanitation service provision

This section illustrates the Climate Capabilities Framework. It demonstrates how dynamic capabilities can enhance operational capabilities along the sanitation chain, beginning with a general framework and two specific examples for the non-sewered sanitation-climate nexus. The overall framework, based on the discussion in the previous sections, highlights the role of dynamic capabilities in improving utility operations.

The Climate Capabilities Framework

The framework comprises the following five elements:

1. **The risk** – This is the opportunity or threat due to disruptions that are likely to affect operations in a utility. It borrows from an organizational perspective that acknowledges the opportunity and threat duality (Bryce et al., 2024) as opposed to the climate perspective, which sees risk negatively as vulnerability, hazards, and exposure (IPCC, 2020).
2. **The capabilities** – these are the specific operational and dynamic capabilities whose interplay is assessed (Teece et al., 1997).
3. **Capability questions** – These questions assess strategic coherence for the operational capabilities, i.e., whether and how sensing, seizing, and transforming occur to inform change through adaptation or innovation for a specific operation.
4. **Outputs of operational and dynamic capabilities** – These demonstrate what is independently expected from dynamic and operational capabilities
5. **Sector transformation, and transition** – This infers whether the outputs of dynamic and operational capabilities likely lead to a transformation in the operational unit or organization, or even a sector-wide transition as an outcome (Warner & Wäger, 2019).

The framework operationalizes how these five components interact to demonstrate an organization's potential to improve or sustain its operations amid internal or external changes and needs. Risk here is defined as the identification and control of uncertainties (Rahi & Bourgault, 2022). It is perceived in two ways: as a threat and as an opportunity. From a threat perspective, capabilities focus on defensive resilience, which comprises loss prevention, compliance, and protection. On the other hand, for the opportunity perspective, capabilities focus on offensive resilience which comprises value creation, innovation, and overall positive gains (Bryce et al., 2024). Both are essential for comprehensive climate resilience in the sanitation sector.

Table 1 presents a conceptual framework for understanding how sanitation utilities can strengthen climate resilience by integrating dynamic capabilities into their operational processes. It maps the interaction between operational activities (core functions such as emptying, transport, and treatment) and strategic dynamic capabilities (sensing, seizing, and transforming) in response to climate risks (threats and opportunities). Its interpretation can be broken down as follows.

Overall, the table is structured with rows representing the utility's operational capabilities **(1)** —the routine, technical activities for sanitation operations. The columns represent dynamic capabilities **(2)** —the strategic processes that enable an organization to adapt, innovate, and evolve. These are divided into three stages: sensing, seizing, and transforming. Additional rows and columns show outputs at both the operational and dynamic levels,

Climate risk (potential threats and opportunities)		**2. Dynamic capabilities (strategic)**			**Outputs for operational capabilities**
		Sensing Identification of the trigger and internal impacts	**Seizing** Mobilizing resources to manage the trigger	**Transforming** Reconfiguring the operational unit and organization	
1. Operational capabilities	Sanitation operation e.g., emptying schedules, transport routes, or treatment processes etc	**3.** How the utility determines how the risk will affect the operation	**5.** How the utility mobilizes resources to manage the sensed impacts of the risk	**7.** How the utility reconfigures itself to embed evolving sensing and seizing insights	9. Consistent and flexible stream of climate funding
	Outputs for dynamic capabilities	**4.** Operation-aware utility	**6.** Operation-adaptive and innovative utility	**8.** Evolving and learning utility	**10. Outcome:** Potential sector transformation/ transition based on the trigger specific to that operation

Table 2: The Climate Capabilities Framework

culminating in a broader outcome that, over time, could influence sector practices for a specific operation.

Sensing capabilities for operations **(3)** assess a utility's ability to determine how climate risks (e.g., flooding, drought) will impact its specific operations (e.g., emptying schedules, transport routes). This involves recognizing threats or opportunities and understanding their potential effects. The output for sensing capabilities **(4)** is an operation-aware utility—one that is informed and vigilant about climate-related impacts on its core activities.

Seizing capabilities for operations **(5)** determine how the utility mobilizes resources (e.g., funds, personnel, technology) to manage the identified effects based on the sensed insights. For example, it might adjust maintenance schedules or invest in flood-proof equipment. The output of seizing capability **(6)** is an operation-adaptive, innovative utility—one that can act swiftly and creatively to address climate challenges.

Transforming capabilities for operations **(7)** determine how the utility embeds the lessons from sensing and seizing into its structure, processes, and culture. This could mean redesigning operational protocols, updating training, or changing organizational hierarchies to institutionalize resilience. Transforming capabilities result in an evolving and learning utility—one that continuously improves and adapts based on experience **(8)**.

In terms of operational capabilities, integrating dynamic capabilities enables climate-resilient operations overall, allowing the utility's core functions to withstand and adapt to climate stresses **(9)**. In dynamic environments, the utility becomes more aware, adaptive, and learning-oriented, thereby enhancing its strategic agility. Ultimately, the outcome of this iterative process can drive potential sector transformation—a shift in how the entire sanitation sector operates in the face of climate change, tailored to specific risks and operations **(10)**

Specific examples for climate capabilities

Example 1: Flood risk capabilities to improve containment and emptying operations for utilities

Latrine overflow due to flood risk as a threat (negative risk)		Dynamic capabilities			**Outputs for operational capabilities**
		Sensing	Seizing	Transforming	
Operational capabilities	Sanitation operation that needs adaptation or innovation: **Containment**	Identifying/mapping potential hotspots for latrine overflow and transport routes at risk of disruption Identifying when flooding is likely to happen (seasonal patterns, weather forecasts, climate modelling) Identifying potential complementary partners, e.g., weather departments, emergency response units, public health departments, and community groups, for prior action before and during overflow events Identifying potential technology/ infrastructure for early warning or floodproofing latrines Scanning the evolution of regulations, standards, and policies relevant to latrines (sanitation) and flood risks (disasters)	Implementing early warning systems for flooding, floodproofing, toilet fill-up sensors, and pre-emptive emptying in high-risk hotspots Designing and activating anticipatory and adaptive processes and contingency plans (e.g., pre-emptive emptying, emergency protocols) with clear triggers and authority. Forming and engaging strategic partnerships for engagement during latrine overflow occurrences and policy engagements	Changing utility strategy from reactive to proactive Reconfiguring the utility's organizational structure to embed new cross-functional teams to manage the threat Changing the utilities' organizational culture towards a more collaborative and partnership-oriented Optimizing and embedding sensing and seizing processes and routines through standardized operating procedures, clear triggers, partnership processes, technology onboarding, and experimentation processes, among others Changing leadership styles where necessary towards more participative and transformational styles	Resilient emptying operations
	Outputs for dynamic capabilities	Multidimensional awareness of flood risks in the containment of the utility's coverage area.	Innovation and adaptation for containment and emptying-related operations in the utility	Evolving utility with embedded and continuously updated emptying operations	Potential sector influence/ authority based on evolving and resilient emptying operations

Example 2: Funding access capabilities for utilities

<table>
<tr><td colspan="2" rowspan="2">Risk: Climate funding opportunities</td><td colspan="3">Dynamic capabilities</td><td rowspan="2">Outputs for operational capabilities</td></tr>
<tr><td>Sensing</td><td>Seizing</td><td>Transforming</td></tr>
<tr><td>Operational capabilities</td><td>Specific operation – funds mobilization for sanitation operations in the chain</td><td>Detecting emerging climate finance mechanisms, pipelines, policy incentives, and carbon markets that create new financing models for sanitation.

Identifying technological innovations in resource recovery (nutrients, water, energy) and assessing their alignment with the operational context.

Interpreting changing stakeholder expectations and market demands for circular, low-carbon sanitation solutions.</td><td>Prioritizing and deploying resources toward the development of climate projects (e.g., biogas generation, nutrient recovery facilities, water reuse systems).

Developing, fund-raising and implementing new climate-aligned services and products (e.g., briquettes, recycled water).

Forming strategic partnerships with technology providers, agricultural sectors, and green investors to scale resource recovery ventures.</td><td>Putting in place systems and processes to transition utility to a regenerative asset base where treatment facilities become resource recovery hubs.

Redefining value proposition from waste disposal to providing circular economy and climate-resilient water supply and sanitation services by utilities.

Leading market creation for sanitation-derived products and influencing policy frameworks that incentivize circular sanitation economies.</td><td>Consistent and flexible stream of climate funding</td></tr>
<tr><td></td><td>Outputs for dynamic capabilities</td><td>A validated pipeline of climate-positive opportunities that create environmental and financial value from utility’s sanitation operations.</td><td>Successfully implemented projects that generate new revenue, reduce operational costs, and/or create verifiable climate benefits from the sanitation value chain.</td><td>Evolution into a climate-positive utility that transforms reusable urban waste flows into valuable resources.</td><td>Potential sector influence where resource loops are closed locally</td></tr>
</table>

4. Potential use cases of the Climate Capability Framework

This framework provides a systematic lens for utilities to diagnose and update their sanitation service-provision operations or underlying processes. It can be adapted for use by utility executives, regulators, investors, consultants, and researchers for potential purposes outlined below.

Internal organizational assessment and benchmarking – utility managers

When fully developed, utility managers can use the framework to audit the evolution of capabilities for updating specific operations or processes and assess the potential to improve and institutionalize them. It can be used to assess utilities' current adaptation progress for each critical operation, including collection and emptying, treatment, resource recovery, and customer service. Such critical operations can be identified using complementary static and general utility assessment frameworks, such as the World Bank's Utility of the Future approach, the PIR framework, or the Inter-American Development Bank's Aquarating. The framework offers a strategic focus that questions: "Can we know? Can we mobilize? Can we reconfigure?" They can also use it to identify capability gaps, as it systematically reveals weaknesses in capabilities to update operations. For instance, is the utility good at sensing climate risks but poor at seizing (mobilizing resources)? Is it stuck in project mode without transforming?

Strategic planning and road mapping – utility managers and consultants

Utility managers and consultants can use the framework to inform the development of a structured strategy linked to climate resilience. The framework moves climate adaptation from a vague "thing we should do" to a concrete strategy with clear pillars: improve sensing (data, models, partners), strengthen seizing (management, funding, technologies), and enable transformation (culture, structure, embedding processes). These will be explored further in future iterations. They can also use the framework for outcome-focused planning. It forces planners to define success not only as completed projects (operational outcomes) but also as enhanced organizational capabilities (dynamic outcomes), thereby ensuring the long-term sustainability of the effort and the utility's resilience. Furthermore, consultants and utility managers can use the framework for mapping transition pathways from a reactive, traditional utility to a proactive, resilient, and potentially transformative one.

Risk management and governance enhancement – utility managers and regulators

The framework provides a clear lens for the boards and executives to oversee climate resilience. They can ask questions such as "How are we doing on sensing for our coastal assets? What is our seizing plan for flood risk? Are we transforming our planning processes?" The Climate Capability Framework can be further developed to provide both leading and lagging indicators for monitoring climate adaptation and resilience. Leading indicators indicate progress in building dynamic capabilities (e.g., new early-warning systems launched, adaptation committees formed). In contrast, lagging indicators indicate the achievement of resilient operations (e.g., reduced outage time during extreme weather).

Sector–level analysis and policy design – regulators, investors, and researchers

A regulator (e.g., Public Utilities Commission, such as WASREB) can use the framework to assess the adaptation preparedness of the utilities it oversees and design incentives or requirements to build specific capabilities based on established needs. Investors can also use it to compare the strategic adaptability and long-term viability of different utilities within their portfolios and identify leaders and laggards. Furthermore, researchers can use it to research the process and evolution of organizational adaptation to climate change, comparing cases across utilities, regions, and types of climate triggers.

Enabling collaboration and innovation – all stakeholders

The framework provides a common language for structured dialogue across utility departments (operations, strategy, finance, research, and development) to collaborate on climate adaptation, breaking down silos. The seizing/innovation link explicitly links resource mobilization to the development of new solutions. This helps justify and direct investments in research and development and in pilot projects.

5. Boundaries and mitigating limitations of the framework

As it stands, this framework is not a complete implementation guide. Its practical use requires deliberately setting its boundaries within a specific context, such as promoting climate resilience, reducing non-revenue water, or promoting resource recovery in a utility. Supplementing these with analyses of external constraints, internal culture, and partnership ecosystems would be required. For overall utility assessments, tools like the Utility of the Future (Cordoba et al., 2022) could be used for complementary diagnosis. Unfortunately, most existing tools have a limited focus on non-sewered sanitation.

Limitation	Ways to delimit/mitigate the limitations
Oversimplified linear view	While both dynamic and operational capabilities are presented linearly, actual operation of the framework should be iterative. For example, transforming should be treated as a new baseline, requiring renewed sensing.
Ignoring critical constraints	A pre-step for organizational context assessment is needed. Before using the framework, it is necessary to map external constraints (regulatory, financial, political) and internal capacities. This sets realistic boundaries for what sensing, seizing, and transforming can achieve.
Vague transformation threshold	Organization-specific indicators need to be defined. Agree that "Transforming" requires changes to formal rules (governance, incentives, organization structure) or core identity, while "seizing" is about projects and processes.
Overly internal focus	An "ecosystem" column could be integrated. This is useful for explicitly analysing the key partners (other utilities, regulators, suppliers, urban planning departments, and communities) required at each stage. Ask: "Who else must sense, seize, or transform for us to succeed?"

6. Potential ways forward for different stakeholders

This framework achieved to facilitate early conversations on dynamic capabilities in water and sanitation utilities. A key call to action for all stakeholders is to experiment with it as a reflexive tool by piloting, refining, and institutionalizing it in their context, while sharing lessons learned. This will facilitate the concept-to-practice transition by developing and testing processes, tools, and shared standards to build climate-resilient sanitation and water services and communities. The following are potential next steps for each stakeholder group.

Utilities can adopt the framework and perform the following four activities. First, they can run deeper, operation or process-specific workshops and apply the framework to their most vulnerable asset or operation to populate the sensing column with concrete data. Secondly, they can use the framework to stress-test scenarios, shifting from generic risks to operational impacts. Third, they can develop operation-specific adaptation plans. These would be for each operation and would mirror the framework as follows: sensing – utility's assessment; seizing – utility's project pipeline and budget; transforming – utility's required organizational changes. Lastly, they can create cross-functional teams that combine operations, planning, finance, and community engagement to lead the reconfiguration process that would likely drive utility transformation.

Private-sector partners (technology, engineering, and finance) can develop solution packages that directly address the mobilization of the required resources. This could include integrated sensor and data analytics platforms or financing models for infrastructure upgrades, thereby supporting the framework's sensing component. They can also partner with utilities on pilot demonstration projects to validate new models within the capabilities framework. The private sector can also offer transformation consulting. This can help utilities with the change management, systems integration, and human resource training required for long-term reconfiguration.

Regulators can use the framework as a lens to assess utilities' operational and strategic capabilities and their potential to drive climate-resilient operations and sector transformations, respectively. Operational capabilities could be evaluated using audit performance metrics that assess the frequency and duration of storm-related failures, as well as the quality of water during droughts. Reviews of post-event reports for lessons learnt could also be conducted.

Potential regulatory tools to influence operational capabilities of utilities include establishing resilience standards, imposing penalties for repeated failures associated with known vulnerabilities, and awarding rewards for superior performance. Dynamic capabilities can be assessed through evidence of learning and systemic change. Examples of these include a utility leading on new business models, driving broader market innovations such as resilience-as-a-service.

Regulators can use regulatory tools to influence utilities' dynamic capabilities. These include catalysing utility transformation through regulatory sandboxes to experiment with new technologies, hosting engagement activities on the future of utility business models and aligning designs with resilience goals. These regulatory opportunities shift regulators from passive oversight to active stewardship of utilities based on their capabilities.

Funders (public and philanthropic) can provide grants to utilities to apply this framework to 1-2 critical operations (e.g., wastewater treatment, resource recovery, emptying logistics). They can fund the "mobilization of resources" phase explicitly, or they can fund the capability gap assessments. They can also catalyze innovation by creating dedicated funding streams for "climate adaptive innovations," supporting partnerships among utilities, technology companies, and researchers. Existing examples include the Solution-oriented Research for Development (SOR4D) programme and Renewable Energy, Energy and Resource Efficiency Promotion in Developing and Transition Countries (REPIC). To enable transformation in utilities, funders can diversify funding streams beyond technology to the process of "reconfiguring" organizational structures, data systems, and human resource development plans. Some funders, such as the Swiss State Secretariat for Economic Affairs (SECO), are already doing this. They can further support existing knowledge-sharing platforms that enable utilities to learn from one another's transformations.

Civil society and community-based organizations can foster community-led sensing. They serve as connectors, translating local climate impacts and vulnerabilities into the operational language of utilities. This ensures that the utility's "sensing" incorporates frontline community knowledge. They can also advocate for the framework's use. Additionally, they can use it as a tool for advocacy to hold utilities and regulators accountable for moving from planning to action. Furthermore, they can facilitate multistakeholder dialogues by bringing together stakeholders, including communities, and using the framework as a neutral, structured agenda for collaboration.

Researchers and academia can quantify and validate the framework through operationalizing its elements. Development or adaptation of metrics for "climate-informed operations" and "climate adaptive innovations" will be necessary. Case studies across different utilities and geographies to test and refine the framework will also be essential. They can also support the development of existing or new standardized assessment tools, such as diagnostic questionnaires, that help utilities systematically work through the "Can the utility determine..." questions for their specific operations. This would be very useful to demystify the sensing aspect of the framework. To support the framework's implementation and transformation, researchers can further study transformation pathways. They can document and analyze real-world examples of reconfiguration and sector transformation, and answer questions such as: what governance, cultural, and technological changes enabled or barred them? Some of these have been done e.g., (SECO, 2016), but not from the agency perspective of the utility and not for nonsewered sanitation service provision. Lastly, once the framework is fully developed, it can be integrated into engineering, public policy, and business school curricula to train the next generation of utility leaders and regulators.

7. Co-development process of the Climate Capability Framework

The PREF4WASH team, in collaboration with the Water Services Regulatory Board of Kenya, conceptualized and developed a preliminary framework in October 2025. The preliminary framework was then reviewed by select stakeholders in the Kenyan sanitation sector before being discussed at a workshop with sanitation stakeholders from local and international NGOs, funders, utilities, social enterprises, and research institutions.

The workshop stakeholder engagements included a pre-workshop survey to identify key climate risks and opportunities affecting non-sewered sanitation systems, as well as potential adaptive actions. Key risks identified included: (1) Flooding: overflow from pit latrines and septic tanks, contamination of water sources, and disruption of emptying operations. (2) Drought: reduced water availability for pour-flush toilets and latrines, affecting services, and (3) Infrastructure and operational challenges that follow floods and droughts, including facility damage, increased maintenance costs, public health hazards, and service disruptions due to unpredictable weather.

The opportunities highlighted included: (1) Climate-resilient designs: elevated or flood-proof sanitation facilities, (2) Resource recovery and circular approaches: biogas, briquettes, compost production, and (3) Access to climate finance: leveraging carbon credits and other mechanisms to support resilient services. Neither the opportunities nor the risks were exhaustively identified or discussed due to time limits.

Respondents emphasized the need for resilient designs, enhanced resource recovery, emergency preparedness for floods and droughts, technical capacity building, improved monitoring and data systems, and leveraging partnerships and climate finance to support sustainable, circular sanitation solutions.

The actual workshop was held on 10th November 2025 in Nairobi. It employed a structured, participatory approach to facilitate collective learning, systematic analysis, and reflection on climate risks and resilience opportunities within the sanitation sector, building on the pre-workshop survey. Expert inputs, guided group work, and plenary discussions enabled participants to move from a conceptual understanding of the dynamic capabilities approach to practical applications for utilities.

The facilitation team introduced the Sensing–Seizing–Transforming framework as a common analytical lens for strengthening climate resilience. Participants worked in small groups to map climate risks and opportunities across the sanitation service chain, prioritize them based on likelihood, potential impact, and utility capacity, and apply the dynamic capabilities framework to determine how risks could be detected early, addressed effectively, and integrated into long-term resilience planning.

Participants were split into four groups for discussions, documented their findings on flip charts and shared them in plenary sessions. This fostered cross-learning, comparison of experiences, and consensus-building. Facilitators guided discussions with probing questions and examples to ensure comprehensive, technically sound outputs.

At the end of the workshop, each participant completed a “Commitment Card” to identify a quick win or significant action they would pursue, ensuring personalized, actionable takeaways for potential implementation and accountability. The facilitator compiled a report for the workshop proceedings afterwards. The framework presented here is based on insights synthesized from the pre-workshop survey, the workshop, feedback from the commitment cards, and subsequent stakeholder reviews.

8. Further reading

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