Urban sanitation and climate change: A public service at risk

Landscape study

Prepared for the Bill and Melinda Gates Foundation

UTS Institute for Sustainable Futures

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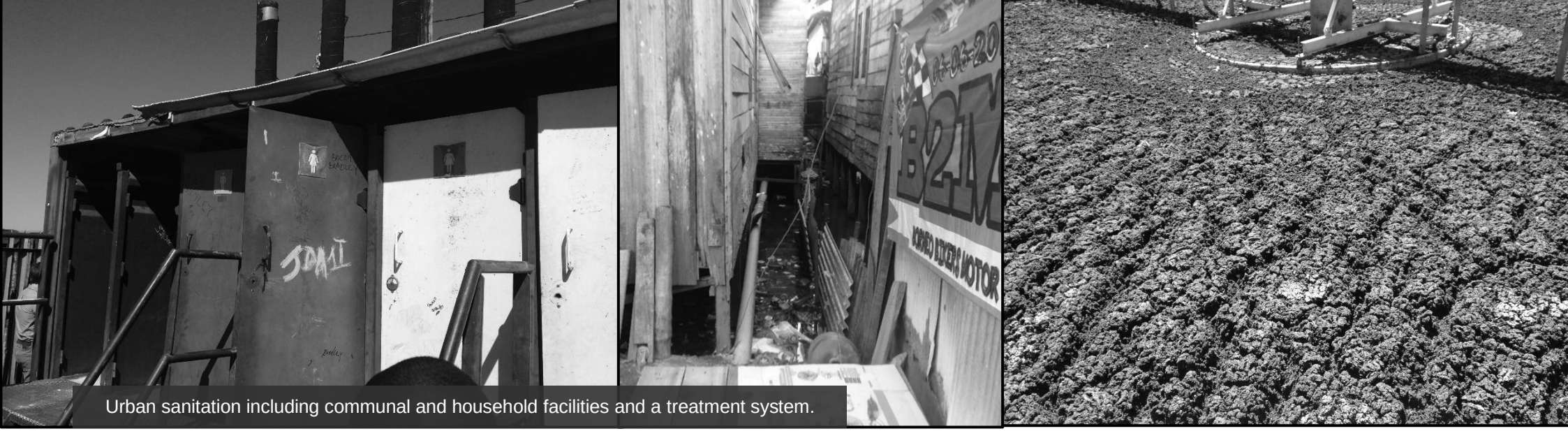

Urban sanitation including communal and household facilities and a treatment system.

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About the authors

The University of Technology Sydney - Institute for Sustainable Futures (UTS-ISF) conducts applied research to support water and sanitation policy and practice in Asia and the Pacific. UTS-ISF provide partners with technical expertise including climate change; planning, governance and decision-making; gender equality and inclusion; public health and water resources management; monitoring; and policy and practice advice.

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Manila Water	National Sanitation Office of Senegal (ONAS)	Practical Action	Programme Solidarité Eau (Ps-Eau)	Department of Sustainable Urban Planning and Development of Royal University of Phnom Penh	RTI International India	EAWAG Department Sanitation, Water and Solid Waste for Development (SANDEC)	Stockholm Environment Institute (SEI)	Stockholm International Water Institute (SIWI)
SNV - Regional, Bangladesh, Nepal	Solomon Island Water Authority	Stantec	Sustainable Sanitation Alliance (SuSanA)	Sanitation and Water for All (SWA)	Toilet Board Coalition	UN-Habitat	UNICEF - Global, Nepal	United Cities and Local Governments Asia Pacific (UCLG ASPAC)
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Executive summary

Climate change is the new operating context for delivery of urban sanitation services rather than a distant imperative. Climate change also puts this public service at risk. Various climate hazards ranging from slow onset events (such as droughts, sea level rise, salinization) to shocks (floods, cyclones) as well as increasing unpredictability are posing challenges to plan and operate sanitation systems and services. In addition, in urban settings in low- and middle-income countries (LMIC) with high population densities, reliance on onsite sanitation systems and increasing climate-induced urban migration, further add to the challenges. Yet without resilient sanitation services, public health and environmental impacts can be expected to worsen.

As a public service at risk from climate change, urban sanitation requires greater attention in climate policy dialogue. Sanitation's interconnections with food security (through safe wastewater re-use), with water supply (to protect groundwater and surface water sources) and with health mean that it could and should form an important pillar in national and city adaptation efforts.

This report presents the outcomes of a Landscape study on the current state of thinking and action on urban sanitation and climate change. Funded by the Bill and Melinda Gates Foundation (BMGF), the study engaged more than 60 organisations from across different countries working on varied aspects of urban sanitation. These included city governments, utilities, national governments, donors, international agencies, private sector implementors, researchers, industry associations, as well as urban development and climate actors. The study was guided by a framework for a climate resilient sanitation system adapted from Willetts et al. (2022), simplifying seven dimensions into four key components important for citywide sanitation. The four components included:

i. institutions, policy and planning;
ii. financing;
iii. infrastructure and service provision; and
iv. user engagement.

While there is a growing evidence base of academic and grey literature on climate change and sanitation, there is a predominant focus on physical climate change shocks and stresses on sanitation infrastructure. Practical examples of adaptation, particularly those incorporating awareness and experiences of users and service providers at the local level, are so far limited, as is evaluation of the effectiveness of adaptation actions.

Yet this Landscape study revealed many promising advances. Current efforts to address institutional aspects include national level integration of climate and sanitation policy and planning, examples of productive cross-sectoral coordination and collaboration and recognition of the value of diverse partnerships. There is momentum driving organisational level commitment to deliver climate resilient urban sanitation programming through internal strategies and guidance, efforts supporting institutional and regulatory reform and use of digital technology to incorporate climate hazards in infrastructure planning. Organisations are exploring new infrastructure options, undertaking risk and vulnerability mapping, and local level government and non-government actors are working to shift service management to better deal with climate hazards. There is emerging research on different ways of measuring resilience, as well as activities to identify the additional costs of resilient sanitation infrastructure and how these could be financed. With regards to user engagement, organisations are exploring communication strategies at the community level to build awareness about climate risks and capacity to cope, adapt and respond to climate hazards. Other efforts promoting local ownership included learning from user preferences, experiences, and community adaptation strategies.

The most significant challenges limiting progress towards climate resilient sanitation included lack of coordinated climate, disaster and sanitation policies, and insufficient budgets to account for increased costs of responding to climate impacts and building resilience. Limited understanding on how to deliver climate resilient citywide inclusive sanitation, and poor use of data about communities and households by local governments, emerged as other prominent challenges.

The report offers a knowledge and learning agenda, to support a rapid shift in practice to better account for climate change impacts. We present six approaches to advance this agenda, each with related topics or evidence gaps:

- Sharing experiences across countries and regions on cross-sectoral coordination, successful and unsuccessful adaptation approaches, etc.;
- Evidence to convince policymakers to invest in climate resilience, such as numbers of people with low sanitation service level access and who frequently experience climate hazards, scale and significance of health impacts, etc.;
- Evidence to inform policy-development, that provides clarity on the additional costs for climate resilient sanitation in different climate contexts, analysis of emissions, along with tools for national level monitoring of resilience of urban sanitation;
- Combined implementation and research initiatives, e.g. in-situ implementation and evaluation of infrastructure in different climatic conditions, initiatives to integrate water supply, sanitation and drainage;
- Local level data collection by government and implementers, on impacts or damage on the sanitation chain in relevant climate events, effects on people's lives, including on vulnerable groups, etc.;
- Academic research on complex questions, e.g. how can synergies and trade-offs in addressing mitigation and adaptation be optimised?

Lastly, the report presents four actions and associated strategies to support efforts to improve climate resilience in urban sanitation, strengthen the argument for this shift and address key bottlenecks limiting progress:

- ACTION 1: Engage with climate policy and better coordinate with urban resilience and other sectors
- ACTION 2: Evolve policy and shift practice to incorporate climate risks and resilience
- ACTION 3: Consolidate and continue to build the evidence base on climate resilient urban sanitation
- ACTION 4: Facilitate rapid learning and capacity building on key risks and adaptation responses

→ ACTION 1: Engage with climate policy and better coordinate with urban resilience and other sectors

- 1a) Seek increased attention to sanitation in climate policy dialogue and mechanisms, through targeted engagement with emissions commitments and national adaptation plans, joint statements, compelling arguments to increase access to climate financing, and further engage with key climate actors aligning to their framing, language and needs.
- 1b) Better coordination and joint work between sanitation and urban resilience, as well as strengthened coordination to achieve mutual benefits in the agriculture, education and health sectors. Integrate expertise across sanitation, urban water cycle and urban resilience processes, including a focus on informal settlements, and actively participate in platforms and networks outside of the sanitation sector (e.g. urban planning, local government associations etc.

→ ACTION 2: Evolve policy and shift practice to incorporate climate risks and resilience

- 2a) Incorporate climate resilience into sanitation policies, strategies and existing citywide inclusive sanitation programming, drawing on 'data for decisions' from risk assessments, and improving local data and monitoring systems. Mobilise utility networks, development banks and donors to play complementary roles to respectively shift practice, match loans with institutional reform, and launch new funding opportunities in climate resilient urban sanitation programming.
- 2b) Incentivise implementers and researchers to work together to generate robust and rapid evidence from current pilots, trials and experiences, either through relevant joint funding approaches or building a research component within implementation projects.

→ ACTION 3: Consolidate and continue to build the evidence base on climate resilient urban sanitation

- 3a) Strengthen thought leadership seeking alignment on key issues through jointly developed briefs, collaborative publication in a well-respected journal and an updated scientific brief on climate and urban sanitation.
- 3b) Building an evidence base beyond technical aspects of climate impacts on sanitation infrastructure, evidence on institutional, financial and social aspects, on emissions as well as resilience, and with active local research and practice leadership. Advocate for funding for research on climate change and urban sanitation, particularly on onsite systems based on priority topics identified in this study.

→ ACTION 4: Facilitate rapid learning and capacity building on key risks and adaptation responses

- 4a) Confirm interested countries and cities with existing resources and interest act as champions and provide 'proof of concept' of new climate resilient approaches, with a mix across cities with different climate issues (flood, drought etc.).
- 4b) Encourage a community of practice through a multi-pronged approach including mobilising existing sector platforms (e.g. SuSanA, FSMA, IWA, CBSA, SWA, SNV D-groups etc.) to engage members on the topic, considering approaches to include a wider set of stakeholders (climate actors, utilities etc.). Ensure focus on climate and sanitation as a theme in upcoming sector events (e.g. SACOSAN, UN 2023).
- 4c) Facilitate knowledge exchange across different contexts to promote rapid learning, ideally including cross-visits or twinning as well as events, taking into account different urban typologies, and promoting local-national interactions and exchanges between LMIC and high-income settings.
- 4d) Address common capacity building needs, through co-developed online short courses and updated curriculum in selected tertiary institutions involved in teaching non-sewered sanitation and based in climate vulnerable countries and regions, and strengthen internal training mechanisms within international and local organisations.The findings from this report can support a strategic approach from international and local actors, increase alignment and commitment to a common agenda to increase efficiencies and avoid reinventing the wheel in each city and country context. With climate change already upon us, there is a critical imperative to act now with this common purpose.

Waterways to which sanitation systems drain in Indonesia.

Contents

Introduction

The purpose of this document is to present findings from a landscape study on urban sanitation and climate change. As a newly emerging and critical area of research and practice, this report provides a point-in-time **snapshot of current thinking and action on urban sanitation and climate change** in 2022. The study highlights areas of focus to date, as well as the directions actors perceive to be important moving forward.

Climate change is increasing the variability and unpredictability of weather patterns. Specifically, climate change is associated with:

- **Slow onset changes:** Effects that emerge over extended periods of time such as droughts, sea level rise, and salinization
- **Shocks:** Events that occur acutely within a short timeframe such as cyclones, heavy rainfall or storms
- **Trends:** Long-term (i.e. over decades) changes in climate variables such as increases in average temperature or average annual rainfall

In turn these changes influence the functioning of sanitation systems and services (IPCC AR6 2022), highlighting weaknesses in such systems and the critical need for increased resilience (see Box 1).

There is **opportunity to bring sanitation into global climate discussions and action**. At COP26 in 2021, a Water Pavilion was convened for the first time, given water's central role in the climate crisis and recognition that "*continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events*." (IPCC AR6 2021). However, sanitation was given little attention. At COP27, with its focus on adaptation, this report and other concurrent work could ensure **greater voice on adaptation issues facing the sanitation sector**, and potential for increased **investment in sanitation, as a basic public service, to improve societal resilience.**

> Changes in temperature, precipitation, and water-related disasters are linked with increased incidences of water-borne diseases such as cholera, especially in regions with limited access to safe water, sanitation and hygiene infrastructure [IPCC AR6 2022].

BOX 1

In this report, resilience is defined as: *'the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure […] while also maintaining the capacity for adaptation, learning and transformation.' (IPCC AR6 2022).*

This report is framed in alignment with the concept of **citywide inclusive sanitation** (CWIS), including a focus on the institutions that comprise the sanitation service delivery system, the whole sanitation chain for both onsite and offsite systems (see Figure 1), and for *all* people within a city, including informal settlements. This is particularly important, since poverty and inequities are amplified by climate change impacts (IPCC AR6, 2022). Some findings may also be relevant to rural areas, but they are not the focus of this report.

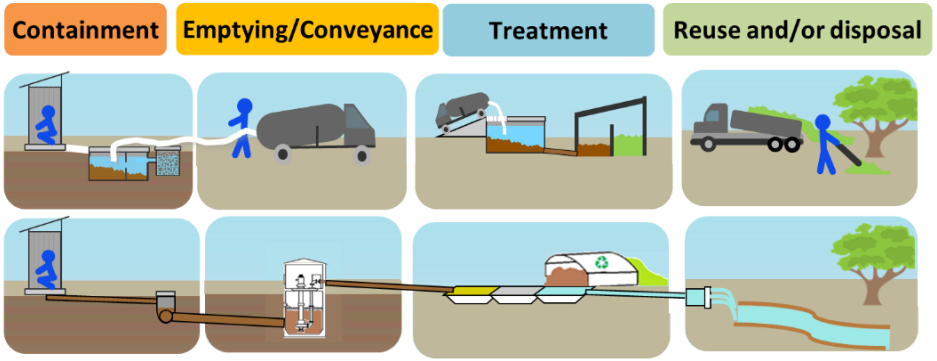


Figure 1: Sanitation service chain for onsite and offsite systems

This report is presented in eight parts. We describe the research approach and methodology, followed by the status of the literature on urban sanitation and climate change. The findings are presented in four sections, focused on current leading practice, challenges, a knowledge and learning agenda and capacity development interests and needs. The report closes with a section on implications for the sector and a conclusion.

1. Research approach and methodology

Study scope

The primary study focus was climate adaptation and resilience across the urban sanitation service chain, including linkages to the broader urban water cycle. Climate mitigation was not an explicit focus but has been included where points were raised by study participants. Solid waste was beyond the scope of this study. Lastly, urban areas were considered to include cities, peri-urban areas and small towns.

Guiding framework

The study was guided by a recently published framework for a climate resilient sanitation system (Willetts et al., 2022), simplifying seven dimensions into four key parts, namely: (i) institutions, policy and planning; (ii) finance; (iii) infrastructure and service provision; and (iv) users (see Figure 2). This framework aimed to encourage thinking beyond the technical aspects.

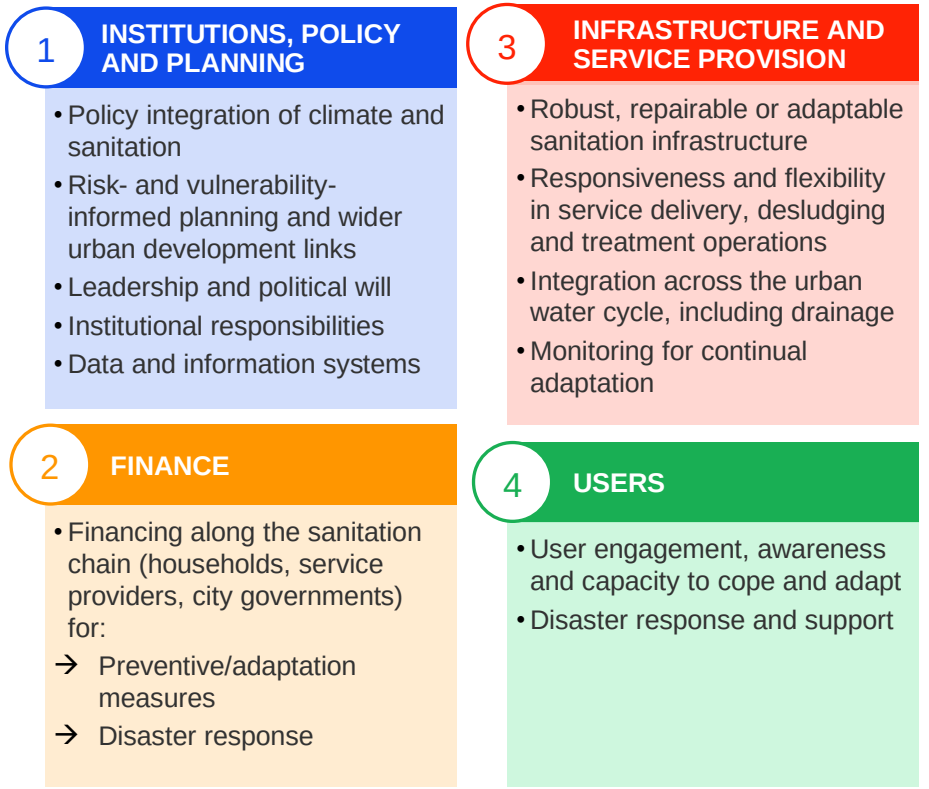


Figure 2: Guiding framework for the landscape study

Urban informal settlements in Bangladesh.

Data collection and analysis

The study took a qualitative, participatory approach and the data collection process was designed to facilitate learning and knowledge exchange. Data was collected from March to May 2022 through a series of 18 participatory online workshops with 96 participants and 17 individual interviews. Zoom meeting platform was used with careful scheduling to enable participation across different time zones.

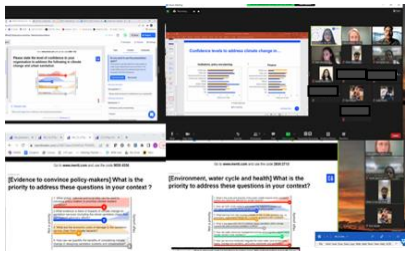
Workshops were organised in two phases (exploration and consolidation) targeting eight stakeholder groups, including urban and climate actors (see Figure 3 and Figure 4). Participatory activities included small break-out room discussions and open- and closed-ended questions and ranking exercises on Mentimeter. Informed consent was sought, and notes were taken during all sessions. Quantitative data was analysed using excel, and qualitative data using inductive thematic analysis techniques.

Phase 1

Objective: To explore the breadth of emerging work and thinking on climate change and urban sanitation, prompt dialogue and collect data

→ **9 Exploratory workshops**

→ **17 Individual interviews**



Phase 2

Objective: To prioritise most important issues and gaps

→ **9 Consolidation workshops**

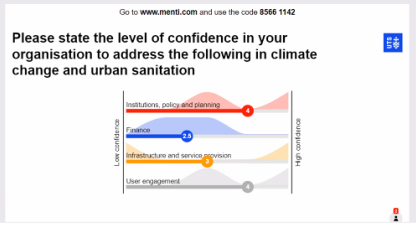


Figure 3: Data collection approach

20	National and city-level actors
15	Civil Society Organisations and Non-Government Organisations
7	Private sector implementors
15	Donor agencies and international organisations
6	Industry associations and networks
14	Research organisations
11	Climate actors working at the interface of sanitation
10	Urban development actors working at the interface of sanitation

Figure 4: Stakeholder groups, with number of participants from each group

Participants were identified through a combined list of UTS-ISF and BMGF networks, organisations identified as publishing or presenting on the topic, as well as through snowballing based on advice from existing participants. There was a specific focus on reaching national and city level partners to learn about in-country perspectives. In all, 98 organisations were invited to participate in the process, and 66 organisations participated. A full list of participating organisations is shown in the acknowledgements section (page iii).

2. Status of the literature on climate resilient sanitation

The literature on climate change and sanitation is steadily increasing since the Vision 2030 (WHO, 2010) scientific brief that drew attention to the issue. At present there is a predominant focus on physical climate change shocks and stresses on sanitation infrastructure, however there is an emerging literature on other aspects, described in brief below. Practical examples of adaptation are so far limited, as is evaluation of adaptation actions.

- **Technical aspects and resilience**: Whilst impact on infrastructure is the area with most literature, a recent review on urban sanitation and climate change demonstrates predominance of studies on centralised systems in high-income contexts, with impacts on non-sewered sanitation under-researched (Hyde-Smith et al., 2022). Studies on flooding and droughts demonstrate multiple failure modes of sanitation systems: collapsing pit latrines; inundation and rising ground water affecting onsite system function; blockage, overflow or backflow in sewers or decentralised systems due to too little or too much water; and coastal treatment systems affected by rising sea-levels (Charles et al., 2009; Takamatsu et al., 2014; Goore et al., 2015; Dzikus et al., 2021; Mills et al., 2021; Nijhawan and Howard, 2022).
- **Institutional aspects**: Recent research describes key dimensions of a climate resilient citywide inclusive sanitation system and city government adaptation responses (Willetts et al., 2022). One aspect is proactive management strategies, such as pre-emptive desludging ahead of wet season, preventive maintenance, systems monitoring and warning systems (UTS-ISF and SNV, 2019; Mills et al., 2020) and improved drainage management (Clemenz et al., 2020). Efforts to assess resilience are underway but not yet agreed (Howard et al., 2021).
- **Financing**: Financing is yet to be an area of significant focus in the literature. Articles so far discuss access to climate finance, which to date has been limited (Dickin et al., 2020). There is little published on the costs of resilient services, with the exception of a World Bank publication, which demonstrates potential for higher costs (Hallegatte, 2019) and a WaterAid blueprint for financing (WaterAid, 2021).
- **User engagement**: Whilst there are many authors, including the IPCC that point out the vulnerability of poor and marginalised groups to impacts on water and sanitation services (Grasham, 2019; Hoque, 2021; Abrams, 2021; IPCC, 2022), there is limited literature on approaches to user engagement. Initial perspectives on strategies to address user engagement are outlined in Indonesia (Willetts et al., 2022) and in programs of key development agencies (WSUP, 2021; Gordon and Hueso, 2021).
- **Climate mitigation**: Degrading faecal matter releases both methane and nitrous oxide. As such, all sanitation systems contribute to greenhouse gases. Research in Kampala found higher-than-expected direct emissions, with operational aspects (e.g. transporting waste) a less predominant source of greenhouse gases (Johnson et al., 2022). Reducing emissions likely requires reduction of storage times under anaerobic conditions (e.g. through more regular desludging of onsite systems), adoption of centralised wastewater treatment systems with capture of gases, or use of dry systems (e.g. composting systems) maintaining aerobic conditions.
- **Health risks**: The various failures of sanitation systems during weather events has been linked to increased health risks (WHO, 2018). Recent research demonstrates potential for return to open defecation during climate events (UTS, UI and UNICEF, 2021). Equally, high risks of pathogen exposure occur in cities when commonly used combined sewers (sewers with stormwater) overflow during heavy rainfall (Goore et al., 2015). Further, heavy rainfall and flooding is associated with increased incidence of waterborne diseases such as cholera, cryptosporidiosis, rotavirus, typhoid and other diarrhoea (Carlton et al., 2014; Levy et al., 2016). Flooding has also been associated with increased skin diseases (Alderman et al., 2012). A study in Bangladesh showed higher E. coli levels in drains in wet season as compared with dry season (Amin et al., 2020).

> Many of the direct and indirect effects [of climate change] on sanitation pose a danger to human health and development (WHO, 2018; 2019)

3. Current leading practice

This section describes the current focus of efforts and different approaches to address climate change impacts in urban sanitation, as shared by participants. Figure 5 shows a lot of focus on national level integration of climate and sanitation policy and planning; robust and repairable infrastructure and technologies; and service delivery, including risk and vulnerability informed planning, and operations and maintenance. There are also some efforts on defining institutional roles, responsibilities and building government capacity to address climate impacts on urban sanitation.

On the other hand, very few organisations are working on establishing climate risk informed standards and regulations to ensure accountability; raising community awareness on different climate hazards, their capacity to cope, adapt and respond to the same; and sector financing for adaptation efforts.

Figure 5: Focus of current work in climate change and urban sanitation (number of participants)

The rest of this section provides specific examples of innovations and recent advances of organisations working towards climate resilience in urban sanitation at the global, national and city level. These are presented under the four categories of the guiding framework (see Figure 2).

Institutions, policy and planning

At the policy and planning level, several national governments have integrated sanitation in climate action plans, recognising them as interrelated issues which mandate a coordinated response. A similar and positive strategic shift was evident among various multilateral organisations.

- **Inclusion of sanitation in climate action planning processes:** At the national level, Nepal has integrated targets for sanitation in their Nationally Determined Contribution (NDCs), while the Kampala City Council has adopted the national climate action plan to the local level, by setting up budgeting and accounting processes which incorporate climate impacts on urban sanitation. Fiji's National Adaptation Plan includes adaptation measures for sanitation.

BOX 2

In Nepal, the Global Green Growth Institute (GGGI) facilitated coordination between the Ministry of Forestry and Environment and the Ministry of Water Supply to integrate sanitation targets in the country's NDCs. The intensive process involved sensitising WASH officials on the potential benefits such as access to climate finance, and building capacity to present their case to the environment ministry.

- **Building institutional capacity:** Bangladesh has plans to formulate a comprehensive national strategy on climate change and sanitation. To support institutional capacity, the country has established a dedicated technical assistance unit (CWIS-FSM Support Cell), with expertise in climate change adaptation and disaster risk reduction, including sanitation in emergency response. This unit is undertaking advocacy to include

sanitation in the country's National Adaptation Plan, with linkages to mitigation as well. Moreover, Bangladesh's recently revised WASH policy incorporates climate risk considerations. In the United States, the Environment Protection Agency established an initiative, Creating Resilient Water Utilities (CRWU), to provide utilities with practical tools, training, and technical assistance needed to increase resilience to climate change.

- **Mobilising political will:** At the international level, the World Bank's Country Climate and Development reports (CCDRs) serve as a strategic tool to initiate dialogue with countries that can generate leadership and political will, and assign institutional responsibilities. While some countries have started including sanitation in their CCDRs, the World Bank is working towards inclusion of WASH in all CCDR documents.
- **Institutional reform:** The African Water Facility at the African Development Bank and the Asian Development Bank are driving institutional reform through their investment lending by taking into account climate change impacts in their sanitation infrastructure development projects and associated institutional strengthening.

A fundamental challenge is that while policy makers have to make multiple decisions at the same time to make things resilient, they lack the institutional arrangements and capacity to support this. The WASH sector needs to support them on these decisions by sharing best practice models on building resilience and adaptation of existing systems.

Many countries are including climate change adaptation and resilience in existing and new water and sanitation policies and planning processes.

Frameworks to support climate resilient WASH: The national planning agency in Indonesia (Bappenas), is developing a climate resilient WASH framework and an SDG roadmap which integrates WASH in climate resilience. These are being prepared simultaneously to feed into each other and to use the opportunity to advocate at the ministerial level and generate political will. Indonesia was the host for the SWA Sector Minister's Meeting in 2022 which included climate change as a theme and also provided a leverage point to advocate this issue at the highest level. Initial work has started on monitoring frameworks, with debate about an appropriate balance of 'process' and 'outcome' indicators.

Integrating resilience in policy development: At a regional level, the African Sanitation Policy Guidelines released in 2021 is an influencial document that highlights the need for sanitation systems, and complementary components such as drainage and urban land use planning and control, to be resilient to climate change.

Incorporating risk considerations in sanitation: In Nepal, UN-Habitat is in the process of reviewing the country's urban sanitation policies, and assessing these for climate risk considerations. Malaysia has a national sewerage planning policy that incorporates climate change considerations for future.

BOX 3

National level planning in Malaysia incorporates various climate change adaptation measures at the utility level. There is an ongoing process to formulate a national sewerage master plan which will include criteria and interventions needed to integrate climate risk considerations. For instance, mapping the climate risk vulnerability of urban areas to help prioritise different zones and make contextual decisions on the kind of interventions needed for each zone.

Progress was visible in institutional coordination and partnerships with diverse actors. Such efforts bring together knowledge from different sectors to make informed decisions on climate resilient sanitation.

Collaboration with climate scientists: In Zambia, national level stakeholders are engaging with climate actors including the meteorological department in the UK, to better understand the linkages between urban sanitation and climate events, to improve access to relevant climate data, involving local authorities in

the process. They are also working across multi-sectoral actors to formulate guidelines for climate resilient sanitation and risk assessment tools.

Draft laws to integrate climate change: Driven by the momentum of COP26, the national government in Vietnam is framing a draft law on water supply and sewerage, including wastewater treatment. The Vietnam Water and Sanitation Association (VWSA) is supporting them to integrate climate change adaptation and resilience in one of the plans, which involves coordinating inputs across their 300 member utilities, civil society organisations (CSOs), research scientists, as well as other government ministries.

Role of local government and non-government actors: Recognising the key role of NGOs and CSOs as first responders to climate hazards at the community level, the Bangladesh government is partnering with them for climate proofing sanitation infrastructure in cyclone shelters by incorporating raised platforms in toilet designs. The national government is also working with BRAC to raise awareness among municipal governments and supporting them by providing loans to deliver climate resilient WASH services.

Many international agencies have developed key strategies and organisational guidance to build adaptive capacity to deliver climate resilient WASH programming. While UNICEF has guidance to support their regional and country offices to address climate resilient WASH, USAID is integrating a comprehensive climate strategy in all their work units, including WASH. The latter is working with utilities to support climate resilient planning, by focussing on governance, utility reform, and utility financing.

There are ongoing efforts of greenhouse gas (GHG) mitigation measures, assessing the scale of emissions from sanitation. The World Bank is working on a GHG accounting tool to understand the direct and indirect emissions from different parts of the sanitation service chain. There is similar work underway by the Green Climate Fund and the Container Based Sanitation Alliance (CBSA). CBSA's upcoming research is exploring ways to process faecal waste into a resource that can be used to offset fossil fuels. Such tools can support decision makers to think about their objectives and assess the various trade-offs while deciding sanitation systems and technologies. The SCARE project (Sanitation and Climate: Assessing Resilience and Emissions) that includes a consortium of actors[1] are measuring emissions from onsite systems and developing resilience metrics in Nepal, Ethiopia, Uganda and Senegal.

At a country level, GIZ is working with water utilities and the national regulator in Zambia to collect baseline data and monitor the GHG emissions from sanitation infrastructure. This is a good example of institutional will on the side of utilities and political will from the regulator, as these organisations conventionally tend to focus on coverage, rather than optimising climate resilience and mitigation.

The role of private sector implementers or NGOs can be crucial to provide climate risk informed evidence to frame regulations and set standards going forward. For instance, in Zambia Lusaka Water Supply and Sanitation Company working together with the NGO BORDA has collected extensive data on demand for pit emptying services and observed seasonal variations with substantial increases during the rainy season. They are using this evidence to support government authorities to develop standards on pit siting, with consideration to areas with a high-water table, in order to minimise overflows during the rainy season.

[1] Led by University of Bristol, and including University of Leeds, University of Technology Sydney, Kathmandu University, Haramaya University, Kyambogo University and Global Green Growth Institute

Financing

On financing, there are initial efforts underway with the WASH community engaging with the climate finance actors, to highlight the specific needs of urban sanitation, as well as emerging research to better understand the benefits and costs of resilient sanitation options, and supporting government partners to access climate finance.

At an international level, USAID's WASH-FIN project is bringing together diverse stakeholders to support financing for sustainable and climate resilient water and sanitation infrastructure. The Asian Development Bank (ADB) is increasingly integrating climate risk components in their development lending projects, including urban sanitation. In addition, a toolkit has recently been developed for climate risk screening of water and sanitation investments (Water Finance Coalition, 2022).

At the country level, the CWIS-FSM Support Cell in Bangladesh has been supporting government partners by linking them to potential climate funders, leveraging their BMGF network, and assisting them to identify climate adaptation solutions which are incorporated in grant applications. Similarly, the Toilet Board Coalition is working on understanding the various business models for sanitation technologies that reduce emissions, and enabling their network organisations to adopt these models and access climate finance. The Water Authority of Fiji is factoring climate risk costs in different parts of their work, including upgradation of their wastewater infrastructure. The process involves collaborating with the Climate Change Division of their Ministry of Economy, and is motivated by their recent Climate Change Act 2021, as well as the recognition of climate resilient sanitation infrastructure in the country's National Adaptation Plan.

> *The momentum around climate change has huge opportunities for funding sanitation. We need to focus on how to access climate finance for sanitation, by building a strong rationale and having a clear message as a [WASH] sector.*

The University of Leeds is looking at different ways to cost and finance resilient sanitation services. The Container Based Sanitation Alliance is conducting research on exploring potential revenue streams from container-based sanitation (CBS). Ideas include back end resource recovery from the waste that can offset fossil fuel use and earning carbon credits using CBS, which has been found to have lower methane emissions compared to pits and septic tanks. There are also emerging examples from high income countries on the potential of using certified climate initiatives (such as green municipal bonds and wastewater bonds) to fund resilient sanitation, but the effectiveness of such initiatives needs to be further evaluated.

Submersible septic tank in flood-prone area, Indonesia.

Infrastructure and service provision

There were many examples of how to adapt sanitation infrastructure and service delivery to address climate risks and vulnerability. This included modifying existing facilities and service arrangements, exploring new technologies and working with partners at the community level to ensure flexibility and responsiveness in service delivery.

Modified toilet design and pit emptying technologies: A water and sanitation utility is embedding climate resilience in the design of toilet facilities, for instance constructing raised facilities in flood-prone areas and adopting innovative technology to manage pit emptying in drought-prone areas. User engagement is central to the design of these interventions.

Preventive actions and appropriate technology: Water & Sanitation for the Urban Poor (WSUP) is implementing innovations in resilient sanitation solutions. In Madagascar they are supporting community-based organisations and municipalities in regular cleaning and maintenance of drainage systems, which reduces stress during climate hazards. Similarly in Nairobi WSUP has supported the utility to pilot simplified sewers which use less water than conventional sewage systems. In the drought-prone area of Livingstone, Zambia, WSUP is working closely with Southern Water & Sanitation Company to develop effective onsite sanitation services to prevent contamination of groundwater which is the area's main source of water supply.

Container-based alternatives: Container based sanitation has worked well to ensure continuity of service provision in areas of frequent flooding where it is difficult to have permanent infrastructure (Haiti) and areas where there is limited freshwater available (Lima). Effective communication initiatives are needed to promote adoption of CBS as a climate resilient sanitation option.

We saw encouraging initiatives by private sector enterprises as well as industry networks. Brilliant Sanitation Limited, a small-scale private enterprise in Uganda, is using innovative technology options such as the Gulper to manage emptying and transportation of faecal sludge in dense urban settlements which are inaccessible by cesspool vehicles during heavy rainfall. They also plan for scheduled emptying that takes into account the high demand during the rainy season. Similar efforts are underway by CEPT University who are working with city governments to ensure provision of scheduled desludging in India. Mandatory desludging is expected to be beneficial in flood-prone areas. Driving private sector engagement in the sanitation sector, the Toilet Board Coalition is conducting research with their network of businesses to understand the role of private enterprises in providing climate resilient faecal sludge management (FSM) services.

> *As a utility, we have embarked on a number of efforts to improve sanitation in the city of Lusaka, embedding climate resilience aspects in the design of infrastructure and service delivery.*

Innovations were also described at the international and national level leveraging digital technology to conduct risk assessments, coordinate across agencies, and plan sanitation interventions more effectively and efficiently, with continuous adaptation through monitoring progress.

Leveraging artifical intelligence and data systems: The World Bank is working on assessing the digital maturity of WASH utilities, and exploring how artificial intelligence can be used to make predictions to mitigate climate impacts or plan sanitation assets better. The Toilet Board Coalition shared experiences of private sector businesses using digital technology to integrate data on sanitation systems with rural-urban migration data to make decisions about future adaptation measures. Digital transformation in this space can increase transparency and accountability through data sharing between service providers, and accelerate multi-sectoral partnerships.

Online platform for hot spot identification: The government of Bangladesh is using innovative tools such as OCTOPUS which is an online collaborative platform to document good practices in FSM disposal and treatment in humanitarian emergency settings across the world. In Bangladesh, this tool is being used to identify climate hot spots for different disasters where sanitation solutions are needed. Similarly in Bolivia and Peru, GIZ is supporting the use of GIS based tools to map and predict different climate risk scenarios, and using this information to adapt urban planning including sanitation, and make decisions about financing.

Digital solutions for CBS collection: Several organistions have developed software to map customers and road access. Initially developed to optimise

CBS collection in cities where certain streets become impassable due to traffic or stalls, this could be adapted to support collection during times of flooding which can prevent certain access routes. Similar solutions are possible to support desludging activities.

Assessment framework for climate resilient urban sanitation: Researchers at Eawag, Sandec are working on a framework to integrate climate resilience perspectives in citywide inclusive sanitation, and testing this in a city in India.

> *The big lesson is that we can't have a blueprint of what makes things resilient – need people to be critically analysing their situation, and tailoring response to their experiences. As is happening in developed countries, it is much less about prescriptive infrastructure management but more adaptive analysis and how to implement climate change adaptations.*

Organisations across the spectrum talked about mitigation efforts to address the impact of sanitation on climate change including adapting existing infrastructure and using circular economy approaches to reuse waste generated from sanitation processes. In Zambia, BORDA is working on different ways to adapt sanitation infrastructure to be climate resilient, with measures such as recommending lining of treatment facilities with sulphur resistant cement so that they can withstand corrosion, designing septic tanks for faecal sludge with low total suspended solids and using biogas digesters for primary treatment of faecal sludge to trap GHG gases which are to be combusted. In Senegal, Ecole Polytechnique de Thiès is working on a multi-sector government funded program to reduce emissions from sanitation waste. This involved building a biogas plant to meet the energy needs of the catchment villages and using the biogas energy for water treatment. The university also explored the potential of sludge as an input for the biogas plant. Similarly, ADB is taking a circular economy approach to mainstream different technology solutions for both onsite and offsite sanitation which promote the reuse of sludge and wastewater.

> *In case of an intense drought, the quality of a treatment plant might be insufficient such that there is less dilution of treated wastewater in the receiving water body. Therefore, this issue needs to be addressed not just by sanitation planners, but we also need to bring specialists from other sectors, such as water quality and biodiversity, into the conversation.*

While nature-based solutions to address climate resilient sanitation are being piloted in some contexts, and the IPCC note ecosystem-based solutions as promising, these are at an early stage in terms of urban sanitation and their success remains contentious. International Water Association's publication on nature-based solutions defines these for wastewater as engineered systems that take advantage of, or mimic, ecosystems, for instance using plants, soil, porous media, bacteria and other natural processes to remove pollutants (IWA, 2021). Since nature-based solutions can be land intensive and hence expensive in an urban context, the Green Climate Fund is taking a small city approach to explore the integration of urban water management, sanitation, and drainage, in green city projects. While land tenure issues make it difficult to pursue these solutions in informal settlements, they may have a potential in other urban contexts.

Latrine water reservoir in Myanmar.

User Engagement

Engaging users and building their awareness and capacity to cope, adapt and respond to climate hazards emerged as a crucial component in which limited, but promising, work was being done at the national and city levels. This included engagement through different communication strategies at the community level, such as working closely with community organisations, learning about community adaptation strategies, promoting local ownership through effective risk communication and understanding user preferences on sanitation.

> *It is very important to consider user perceptions and preferences since they typically have a reason for this. A paper showed that while sewers were proposed to a set of low-income households, they rejected the idea. The researcher found out that this was because the area faced frequent water shortages and the community wouldn't have water for flushing.*

In Lusaka and Indonesia user experiences were sought and incorporated in designing toilets for flood-prone areas. Kyambogo University in Uganda is also working on community engagement strategies and shared examples of community adaptation efforts, such as building raised pit latrines above the flood level and other coping strategies to manage impacts of floods and drought on sanitation. Such efforts to understand user perceptions and preferences for sanitation options are important for designing infrastructure and systems based on local contexts, and cultivating local level resilience amongst communities.

Grassroots organisations can play a strong role in seeking buy-in from the community, ensuring sustainability of services as well as gathering local level evidence. The African Water Facility shared examples from Togo, a low-income country vulnerable to climate shocks, where they trained community-based organisations to successfully manage sanitation infrastructure. The Vietnam Water and Sanitation Association also works with local NGOs to raise awareness about water resource management and the need to reduce pollution from sanitation systems. The CWIS-FSM Support Cell in Bangladesh has formulated a risk communication and community engagement strategy for urban and rural sanitation to enable community mobilisation and local ownership. Other organisations talked about the potential of grassroots associations to collect data on climate impacts from slum areas or informal settlements, which could be useful for local governments to plan sanitation interventions in uncertain climate scenarios.

> *Need to also include community and grassroots organisations in addressing climate change. There are lots of examples of their strong role in getting households connected to sewer or water networks or their role in slum upgrading which include sanitation. They are also very good at collecting reliable community level data which can serve as evidence for making decisions at the local government level.*

Communal toilets with underground containment

4. Common challenges limiting progress in climate resilient urban sanitation

The following challenges were raised by participants as the top five most significant in limiting progress towards climate resilient urban sanitation. These challenges are a combination of on-going sector challenges, and those specific to addressing climate resilience. These top five challenges in each area were distilled from an extensive list of challenges. We give primacy to the view of in-country stakeholders closest to the issues, and note where views aligned or differed from international actors.

Institutions, policy and planning

The most significant challenges faced by both in-country and international stakeholders are shown in Figure 6, with lack of coordinated climate, disaster and sanitation policies deemed the most significant challenge. Besides gaps in expertise and coordination with disaster management, participants expressed the difficulty to convince climate stakeholders of the importance of including urban sanitation in their mandate, at both global and national levels. Participants also repeatedly pointed to the lagging status of sanitation and its low policy priority, noting that this needs to be changed before it is possible to start talking about climate resilience.

> *There is a lack of coordination between disaster management authorities and water and sanitation planners, particularly at the local level. There is no WASH knowledge and expertise in disaster management authorities, and this can lead to public health concerns in the aftermath of disasters.*

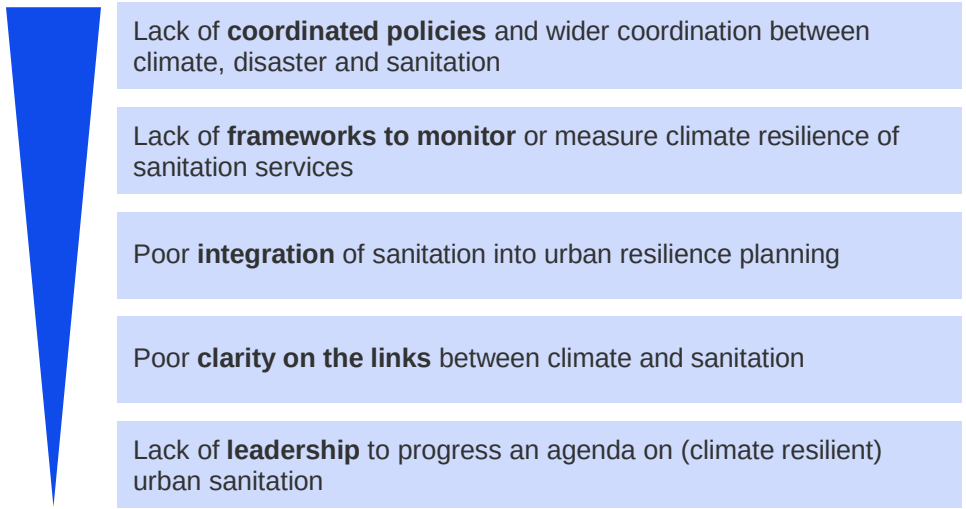


Figure 6: Most significant challenges: Institutions, policy and planning (high to low for in-country-actors)

Other commonly cited challenges included lack of key accountability mechanisms, disconnect between policy and implementation, limited policies on non-networked sanitation which limits the incentives to promote onsite options as an adaptation measure in relevant contexts, and lack of an enabling environment for the private sector and users to invest in climate resilient sanitation.

Financing

In-country stakeholders highlighted insufficient budgets to account for increased costs of climate resilience and adaption as their most significant challenge (see Figure 7), whereas international actors prioritised access to climate finance and finance for integrated systems. Inadequate budgets related to lack of clarity on the required life-cycle costs when considering climate risk scenarios and expected higher capital and operating costs, and challenges to include 'resilience' as a budget line, particularly due to the grant/project-based lending approach. For international actors, the restricted view of global climate financers perceiving sanitation investments as 'development' rather than 'adaptation', the need for proof that impacts are climate-induced, and lack of clear resilience metrics are impeding progress. Additionally, the challenge of results-based financing and incorporating long-term impacts in a context of climate resilience and uncertainty resonated with the international actors.

- Sanitation **budgets do not account for the costs of resilience** and adaptation (both increased capex and opex)
- Lack of **evidence on economic impacts** of non-resilient sanitation
- **Low capacity to estimate the costs** involved in implementing climate resilient sanitation policies and plans
- Lack of evidence and skills in the sanitation sector to pitch for **climate finance**, no strong 'climate rationale'
- Lack of **financing opportunities for systems-level planning** (e.g. for an entire city)

Figure 7: Most significant challenges: Financing (high to low for in-country-actors)

> *It is difficult to have a budget line item for 'resilience' which gets marginalised or diluted among the usual 'tangible' budget headings.*

> *Often, the operations or maintenance budget for sanitation infrastructure projects is underestimated, as it does not account for climate impacts. Appraisal for loans or grants do not have a mechanism to check the life-cycle costs of operation of infrastructure accounting for climate change.*

Map of sewerage connections in Indonesia.

Infrastructure and service provision

Lack of understanding as to how to deliver climate resilient citywide inclusive sanitation was the most significant challenge for both in-country and international stakeholders, with limited access to climate data that can be linked to sanitation impacts also deemed a key issue to overcome. City and national participants particularly found it challenging to retrofit adaptation measures to existing urban infrastructure which is often a combination of onsite and offsite systems, due to lack of guidance and design standards. Other common challenges included lack of consensus on what constitutes climate resilient sanitation technologies and a limited understanding of the potential of circular economy of sanitation.

> *There is a lack of guidance to plan for climate considerations with different types of sanitation systems. Most urban centres have mixed onsite and offsite systems. It is a challenge to work with different types of services and combined sewerage with stormwater and address climate change.*

- Lack of **understanding** on how to deliver climate resilient citywide inclusive sanitation
- Limited **access to climate data** to establish baseline conditions and prepare for the future
- Lack of **evidence, guidance and design standards** for climate resilient infrastructure/technologies
- Absence of **climate risk considerations** in existing planning and infrastructure
- Limited knowledge of **circular economy and nature-based solutions** and how these could help

Figure 8: Most significant challenges: Infrastructure and service delivery (high to low for in-country-actors)

Container-based sanitation transportation in South Africa.

User engagement

The challenges faced in engagement with households related primarily to absence of ways to address community awareness and behaviour, however the most significant challenge for in-country and international stakeholders was the poor use of data about communities and households by local governments. Participants also highlighted the urgent need to involve diverse community members in risk analysis and planning processes in order to identify local and contextual needs. Raising awareness of the climate impacts on onsite systems, beyond the user interface of a toilet, particularly the importance of resilient containment systems was cited as a common challenge.

> *From a user [household] perspective, sanitation is the first priority and climate change is secondary.*

- Poor **use of data from households** and communities by local governments
- Lack of known **effective behaviour change strategies** for climate resilient sanitation
- Lack of community-level **awareness about climate change**
- Lack of awareness amongst users on **safely managed containment** and faecal sludge management
- Lack of clarity on the **role of households** in addressing the issue

Figure 9: Most significant challenges: User engagement (high to low for in-country-actors)

Semi-permanent latrine in Bangladesh in close proximity to a water point.

5. Research, knowledge and learning agenda

In this section we describe a proposed knowledge and learning agenda based on the priorities of different groups of participants, and with a view to how this agenda might serve different purposes and be actioned (see Figure 10). Secondly, we present evidence gaps as prioritised by different groups (in-country sanitation actors, international sanitation actors, and the full sample which also includes climate and urban actors). Further information is available in Annex 1 on the prioritisation of evidence gaps by in-country and international groups, including aggregated priority across all participants.

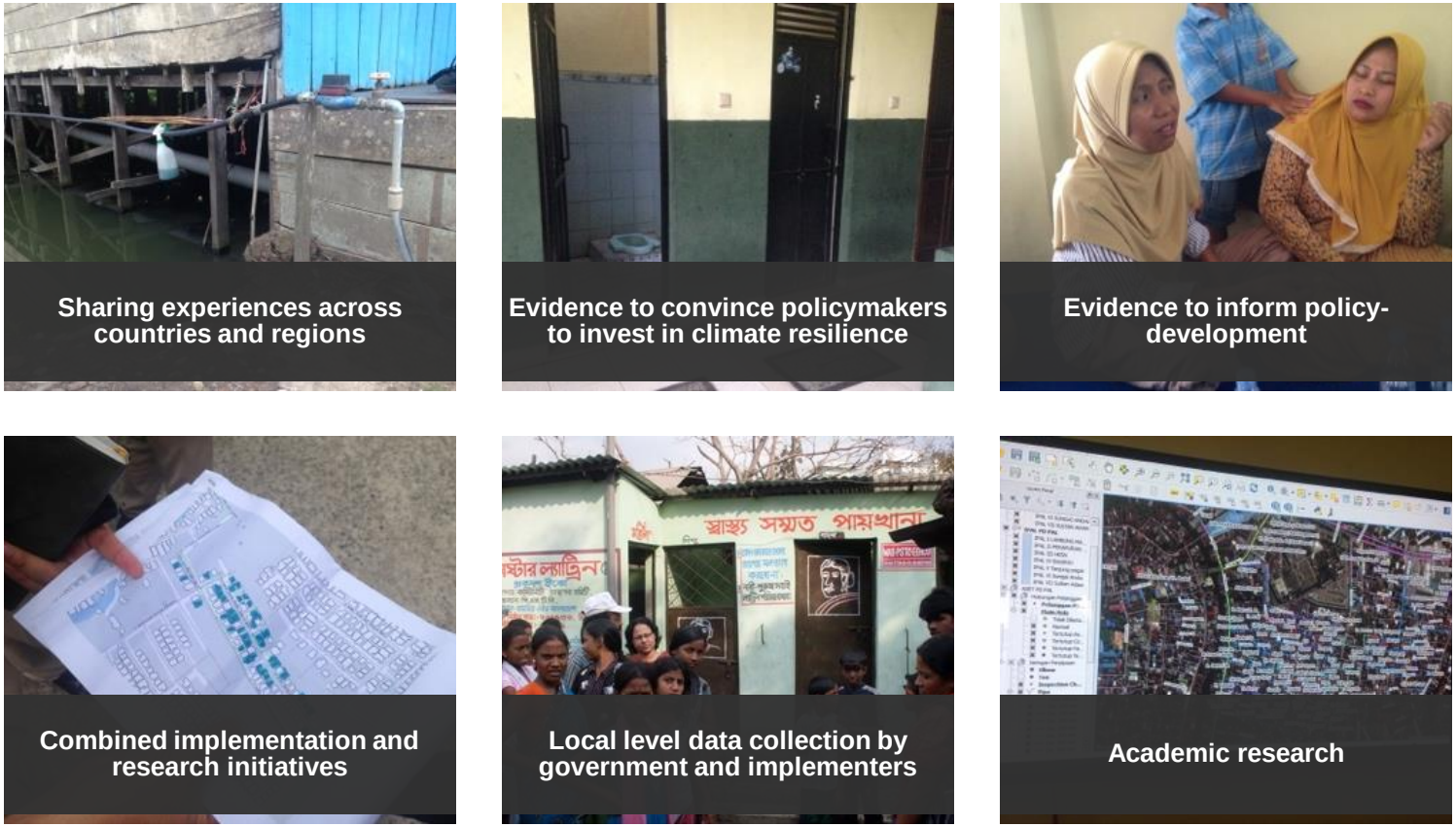


Figure 10: Framework for the knowledge, learning and research agenda to progress climate resilient urban sanitation

5.1 Sharing experiences across countries and regions

Many of the topics raised by participants are appropriate for knowledge exchange. These activities don't necessarily require detailed research investigations, but rather, facilitated dialogue between different stakeholders and country contexts. Such knowledge exchange is likely to be most beneficial across different regional and country contexts, to accelerate cross-fertilisation of ideas and experiences and avoid 'reinventing the wheel'. There are a range of ways to achieve such sharing, including forums, twinning, webinar series, virtual or face-to-face field visits and compilation of case studies.

Institutional topics

- Case studies of successful national-level institutional coordination
- Examples of convincing policymakers to act using data/evidence of impacts on services and related costs
- Cases of cross-sectoral coordination between agriculture and wastewater to support mitigation (e.g. biogas)
- Cases of sanitation agencies coordinating with local level disaster management
- Experiences of monitoring climate resilient service delivery at the city level
- Experiences to develop the capacity of service providers (such as masons etc.) to build climate resilient infrastructure
- Experiences of using climate data and climate scenarios for city-level sanitation planning
- Innovations in FSM service delivery arrangements that enhance adaptation
- Experiences of translating policy to on-the-ground implementation
- Experiences and messages of WASH ministers communicating outside the sector to others ministers (environment, food and agriculture) on how climate resilient WASH solutions contribute to national level adaptation
- Experiences of integrating cross-border and cross-sectoral climate change impacts in planning national level policy and regulations
- Experiences of adaptation and mitigation efforts by utilities which can be used for adaptive/dynamic decision making by regulators

Financing topics

- Experiences of other sectors (such as energy, agriculture) in accessing climate finance

Infrastructure and service provision topics

- Successful and unsuccessful adaptation responses
- Lessons from infrastructure built without consideration of climate change
- Emerging responses to modify and adapt existing infrastructure to be more resilient
- Experiences and results of nature-based solutions
- Experiences of addressing flood impacts on contamination of ground and surface water
- Experiences of improving faecal sludge management to reduce emissions and contamination
- Examples of circular economy applications and innovations that address resilience
- Examples of use of container-based sanitation to increase resilience
- Cases of effective integration across the urban water cycle

User engagement topics

- Methods to raise awareness among diverse users on climate change, impacts and rationale to invest in resilient sanitation facilities

> *Twinning with other water utilities doing similar work would be useful. We would like to learn about which are the water utilities that are moving towards a climate resilient scenario; how they are doing this and what can we learn from them.*

5.2 Evidence to convince policymakers to invest in climate resilience

Several evidence gaps lend themselves to data gathering or research to make substantiated arguments to policy-makers for increased attention to urban sanitation and its climate change impacts. These areas should be considered high priority given the low investment in the sanitation sector. Key areas included:

- **Numbers of people** with low sanitation service level access *and* who frequently experience climate hazards? (globally, nationally, locally)
- **Scale and significance of public health impacts** when sanitation systems are adversely affected by climate hazards
- **Service chain impacts** of climate change and climate hazards including all parts of the chain, both for onsite and offsite systems
- **Economic costs of damage and disruption** to the sanitation service chain from climate hazards
- **Quantified benefits of climate risk considerations** when designing sanitation systems and infrastructure

> *We have a lack of alignment as a sector on climate change and urban sanitation and need a decisive global authority who can talk on the returns on investing in climate resilient sanitation, consensus on three to four key statistics, with coordinated messaging. Currently there are too many solutions, perspectives and technologies.*

5.3 Evidence to inform policy-development

For stakeholders at the national level, there were key priorities that must be addressed to support evidence-based policy-making. These included:

- Clarity on the financing costs, particularly the additional cost, for climate resilient sanitation in different climate contexts (urban, coastal, low-lying, hilly/mountainous)
- Frameworks, information systems and indicators to enable national level monitoring of climate impacts and the relative resilience of urban sanitation services and systems
- Analysis of emissions along the sanitation chain
- Tools and good practice for effective translation of policy to on-the-ground implementation
- Potential for pathogen transmission and human exposure through drainage systems, groundwater and surface water, including mapping to predict spread during climate events, and responses to address high-risk situations and locations

> *We [utilities] need data on salinity which will impact water treatment plants. How do we cost for climate risk in sanitation infrastructure; what are the different options when we account for salinity – do we move treatment plants to higher ground; what are the cost implications of such decisions.*

5.4 Combined implementation and research initiatives

Climate change is occurring rapidly, and hence combining implementation with research can capture evidence and learning from climate resilient programs or approaches to facilitate rapid learning and course correction across the sector. The research role could be to document pilot interventions, trials or implementation practice; to synthesise findings across contexts; and/or to evaluate effectiveness. A key point raised multiple times was the need to **address adaptation and mitigation together**, such that energy efficiency, emissions reduction, water efficiency, and climate proofing of sanitation services are considered together.

Key topics that should be addressed in such initiatives include the following:

Institutional

- Implementing strategies to strengthen institutional capacity to monitor resilient service delivery
- Cross-sectoral coordination of agriculture and wastewater to support mitigation solutions (e.g. biogas)
- Initiatives to integrate water supply, sanitation and drainage to increase climate resilience
- Effective communications to various sanitation stakeholders (such as CSOs, service providers) on disaster preparedness and recovery, not just response
- Develop and apply frameworks and indicators to monitor climate resilience of sanitation infrastructure and services
- Incorporate damage to sanitation facilities in disaster policies and processes, appropriately recognising the relevant repair costs
- Identifying the knowledge gaps and capacity building needs of urban planners/engineers to enable them to retrofit climate change adaptation to existing infrastructure

Financing

- Feasibility of mobilising disaster management budgets for disaster response in urban sanitation, including assessment of how short-term implementation of these budgets can also support long-term improvements
- Experimentation with financial models to ensure sustainability and viability of service providers given climate hazards
- Trial business models that support private sector to incorporate climate considerations

Infrastructure and service provision

- Implementing and evaluating nature-based sanitation solutions
- In-situ implementation and evaluation of technologies and infrastructure in different climatic conditions, including assessing the value of building in redundancy
- Implementation and evaluation of adaptation responses (in infrastructure or management arrangements)
- Use of city-level risk assessments to inform adapted plans for service delivery
- Evaluate different strategies to strengthen capacity of service providers in preparedness for events
- Trial innovations in climate resilient FSM
- Experimentation with the role of container-based sanitation to improve resilience

User engagement

- Implement and evaluate strategies to raise awareness amongst households on climate change and impacts on sanitation
- Trial methods to shift household behaviour to proactively manage sanitation facilities ahead of events
- Pilot strategies to overcome reluctance of users to invest in climate resilient sanitation facilities
- Communication of the costs of climate resilient sanitation infrastructure to help users to make better informed decisions
- Implementing successful learnings from the open defecation free movement, which encouraged community engagement, and adopting these principles to mobilize users for climate resilient sanitation

5.5 Local level data collection by government and implementers

To inform local decisions and priorities, local data collection is critical, and is a key priority for local authorities and those that support them. Key data needs for planning and implementing resilient services include the following:

Institutional

- Overlay mapping of sanitation facilities, socio-economic levels, service levels and climate hazards
- Local climate data, scenarios and predictions to inform planning
- Monitoring approaches to track climate resilience of service delivery at the city and household level
- Incorporating climate risks into planning
- Data-sharing on climate migrants to support service planning
- Effects of climate related urban migration on urban dwellers and sanitation services

Financing

- Financing costs for climate resilient infrastructure, including additional costs compared with business as usual
- Repair costs for sanitation facilities damaged by climate events

Infrastructure and service provision

- Impacts or damage on the sanitation chain in relevant climate events
- Mapping of onsite systems and sewers to predict spread of contamination during flooding events
- Data from diverse geographical contexts on emissions from onsite sanitation systems, to compare benefits of certain infrastructure options over others

User engagement

- Experiences of community groups' (women, people with disabilities, other vulnerable groups) impacts on sanitation services
- Effects on people's lives of climate impacts on sanitation, including the secondary impacts on livelihoods, health, migration etc.

Birdseye view of Dhaka, Bangladesh.

5.6 Academic research

Academic research can be forward looking, to examine complex questions that help provide answers to required changes in policy and practice. Research can also cover areas that are included in other categories, but provide a more rigorous and detailed assessment. These have been captured as key research questions rather than topics.

Institutional

- How can mapping of sanitation facilities, infrastructure, service levels, climate hazards, socio-economic and other data be overlaid to inform planning processes?
- What are some examples of adaptation actions that improve sanitation infrastructure resilience and promote preventive solutions (rather than disaster response)?
- What are appropriate ways to integrate water supply, sanitation and drainage and how can this be done in practice and tailored to context?
- What are successful and unsuccessful adaptation measures to support more resilient urban sanitation services?
- What frameworks and information systems are needed to enable national level monitoring of climate impacts and resilience of urban sanitation?
- What frameworks could support city-level risk assessments to inform planning of service delivery?
- At country level, what are the capacity building needs to incorporate climate risks into policies?
- At city level, what are the capacity building needs to incorporate climate risks into service planning?

Financing

- What financial models for service providers can support sustainable provision in the face of climate hazards, given user charges may be insufficient?
- What are the financing costs for climate resilient sanitation in different climate contexts (urban, coastal, low-lying)? What is the additional cost?
- What are the opportunities to capitalise on climate finance to bridge the gap between costs of adaptation and what households are able and willing to pay?

Infrastructure and service provision

- If and how are current services coping with climate variability? How can this inform what it means to adapt to uncertainty of climate change?
- What are the expected impacts or damage on urban sanitation infrastructure (onsite systems and sewerage) along the whole chain in different climatic contexts?
- What are the emissions along the sanitation chain? How can emissions reduction and improved resilience be achieved together?
- What are the organisational level impacts of different climate hazards for service providers? (e.g. coping capacity and productivity of employees of a utility during consecutive days of heavy rainfall and flooding)
- What is the role of nature-based or green-based solutions in adapting sanitation infrastructure and services to climate change?
- What technologies are needed for different contexts and climatic conditions? (coastal, low-lying etc.)?
- What indicators can measure the climate resilience of sanitation infrastructure across varying climatic, geographic contexts?

User engagement

- What are experiences of different community members (women, people with disabilities, other vulnerable groups) of climate change impacts on sanitation services?
- How are people's lives affected by climate change impacts on sanitation, including the secondary impacts on livelihoods, health, migration etc.?
- How can an understanding of the costs of climate resilient sanitation infrastructure help users to make better decisions?

Priority knowledge gaps according to urban actors

As climate change requires an integrated citywide resilience approach, collaboration in knowledge generation with urban actors is critical. Evidence gaps and knowledge needs prioritised by urban actors participating in this research, could form the basis of **joint work between urban development and urban sanitation actors**. A particular focus of many international urban development actors is **informal settlements**, and this should be a core joint area of focus since such informal settlements are often vulnerable to climate change impacts.

Urban actors prioritised many areas concerning institutional arrangements and capacity. These included how to build capacity at national and city levels, and how to translate national policies to local implementation plans and regulations. Another priority gap was engagement with disaster response, to shift financing through local resource allocation to preparedness and prevention, and how to facilitate a better response for urban sanitation. Priority issues of coordination and integration requiring new evidence included enablers of effective institutional coordination, particularly for how urban, wastewater and agricultural sectors could support combined mitigation and adaptation solutions.

> *How do governments see the issue of resilience? It is not just contained in the sanitation sector. There are bigger planning processes of resilience, and there are lots of other issues in the larger urban development framework. How can we ensure urban policies and processes reflect the priority of sanitation?*

Concerning infrastructure, the highest priority topics for urban actors included expected damage on urban sanitation infrastructure in different climatic contexts, and examples of successful and unsuccessful adaptation measures, including effective nature-based solutions. In relation to service delivery, urban actors prioritised climate data for informed decision-making, frameworks to support city-level risk assessment, and coping of current services as the basis for adaptation. As regards user engagement, urban actors prioritised gaps in understanding how to raise awareness amongst diverse users on climate change, and how to prioritise community-driven assessments in informal settlements.

> *We need generation of data by communities themselves. Grassroots fed – and which can contain incredibly detailed information. Data generated by communities with a desire to work with local government. With guidance, such approaches could also address climate change as it affects their settlements.*

For financing, the highest priority gap was on mobilising and increasing local level disaster management budgets for sanitation. Urban actors also placed priority on several evidence gaps concerning the water cycle, including flooding and associated pathogen pathways and effects of poorly managed faecal sludge.

> *We cannot think of sanitation without thinking about drainage.*

> *Some urban water cycle integration has been attempted, but we need more of this. How do we justify these types of interventions, the required investment, and how do we link the benefits with resilience? This would be helpful research to do.*

Priority knowledge gaps according to climate actors

Increased attention in climate policy dialogue and robust technical solutions requires climate advocates, climate scientists and urban sanitation professionals to pursue joint knowledge generation. Key areas of priority for climate actors participating in this research could also form the basis for such joint efforts.

Climate actors prioritised topics that could support service providers and cities to use climate data and climate scenarios at city-level to inform decisions, to conduct city-level risk assessments, and to improve communications in support of disaster preparedness and recovery. They also gave high priority to understanding the impact of flooding on pathogen transmission through drainage systems, groundwater and surface water and potential for human exposure, and understanding if and how current services are coping with climate variability and how this could inform adaptation to the uncertainty of climate change. Climate actors considered it important to build up examples of adaptation actions that improve sanitation infrastructure resilience and promote preventive solutions, as was cross-sectoral coordination for combined mitigation and adaptation solutions.

Concerning financing, climate actors prioritised understanding the additional costs required for climate resilient services in different climate contexts and examining financial models for service providers that can support sustainable provision in the face of climate hazards, given user charges may be insufficient.

Climate actors were also concerned about the limited evidence base to support links between sanitation and broader societal adaptation, which would be needed to access climate finance.

> *The link [for sanitation and climate] has been very clear for mitigation, for adaptation it may be different. It is not very clear when you talk to climate scientists still, and even though we have the SDG targets, the IPCC reports etc. we haven't clarified the link.*

> *From my perspective as someone that tried to attract climate finance from Green Climate Fund for sanitation, we found that the guidelines for sanitation were absent. We can try to make climate resilient sanitation systems, but that won't ensure financing of sanitation from climate funders. We need to look at how sanitation can help adaptation, however the frameworks for measuring the impact of wastewater treatment systems and faecal sludge management on adaptation are missing. We need to generate evidence, that proper faecal sludge management would support adaptation, and need a framework to measure this impact.*

Urban latrine in Laos.

6. Capacity development interests and needs

This section describes areas of low confidence to address climate impacts on urban sanitation and topics identified by participants as important to receive capacity building support. It offers insights to understand current skill gaps and topics that warrant the greatest priority for development of a learning curriculum and content. At the same time, it can be useful to note the areas of high confidence as this can help to enhance existing skills and scale up aspects that are working well.

Amongst in-country participants, addressing financing for climate resilient urban sanitation was the topic of least confidence, demonstrating an area of need (Figure 11). There was significant variation in confidence levels across different groups, such as government, civil society and researchers. For international actors, both financing and user engagement were the lowest areas of confidence.

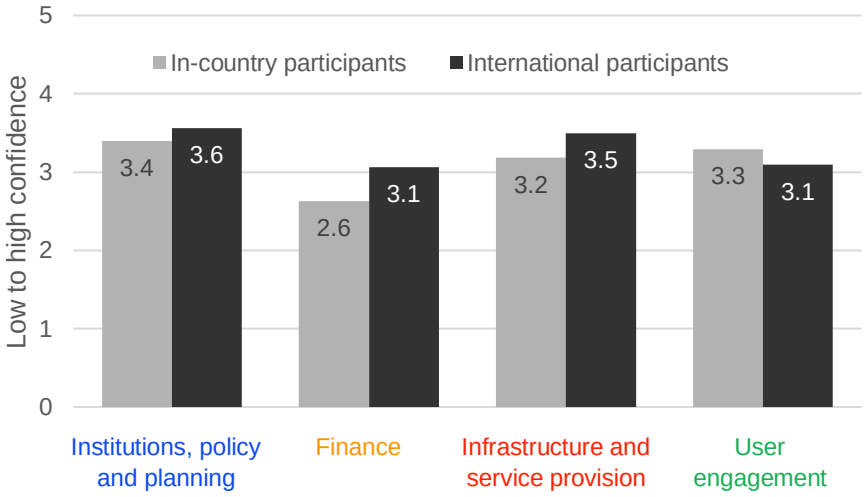


Figure 11: Average confidence level to address climate change in urban sanitation by in-country and international participants. Scores are on a scale of 0-5

Institutions, policy and planning

Top areas for capacity building, with interest from both in-country and international participants, included city-level risk assessment processes, climate resilient national and local level planning (of urban sanitation), and ways to integrate sanitation while planning for resilient cities (Figure 12).

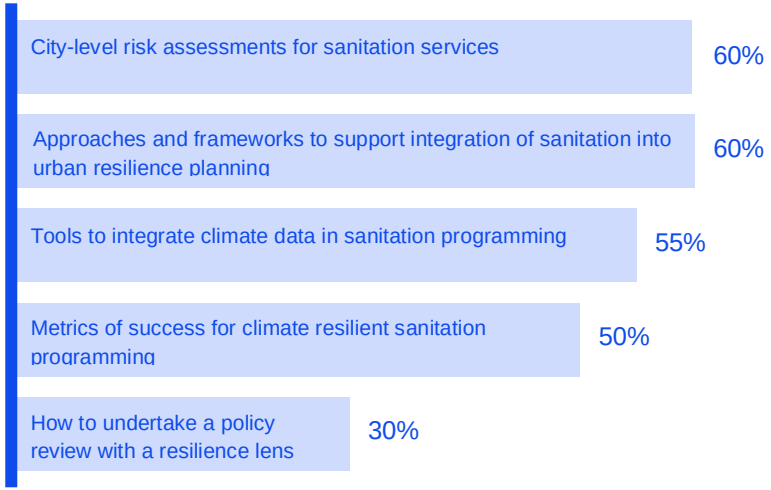


Figure 12: Capacity building needs with regard to Institutions, policy and planning. Proportion of participants interested in capacity building on this topic (n=60).

> *Actually, I think it's more useful to have training on higher confidence areas where we are more likely to sharpen or scale what is working. For us that would be climate resilient regulation and policy and climate resilient sanitation safety planning.*

Financing

Capacity building needs in financing climate resilient urban sanitation showed some variation across in-country and international actors. While in-country actors sought support in financing options to improve climate change adaptation action plans and effectively directing this to urban sanitation, international actors were most interested to learn more about the successes and failures of other sectors (such as energy, agriculture) in mobilizing resources from climate finance. Building government capacity in planning and mobilizing local level financing emerged as a common topic of interest across participants (Figure 13).

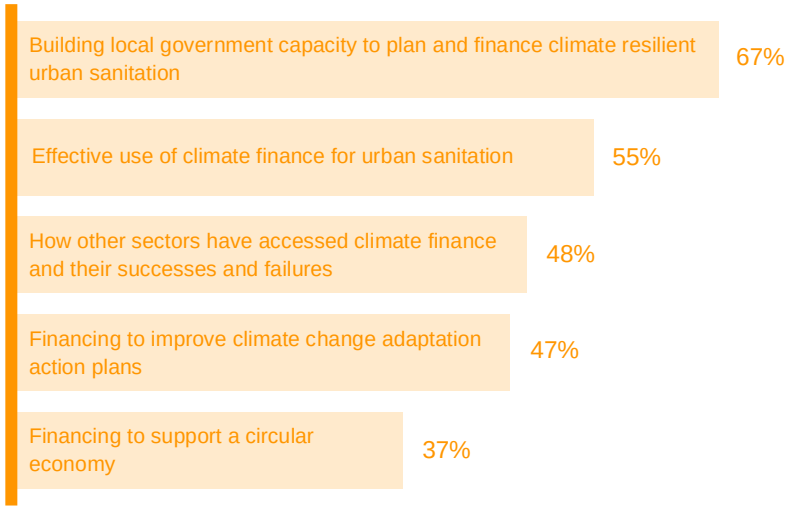


Figure 13: Capacity building needs with regard to Financing. Proportion of participants interested in capacity building on this topic (n=60).

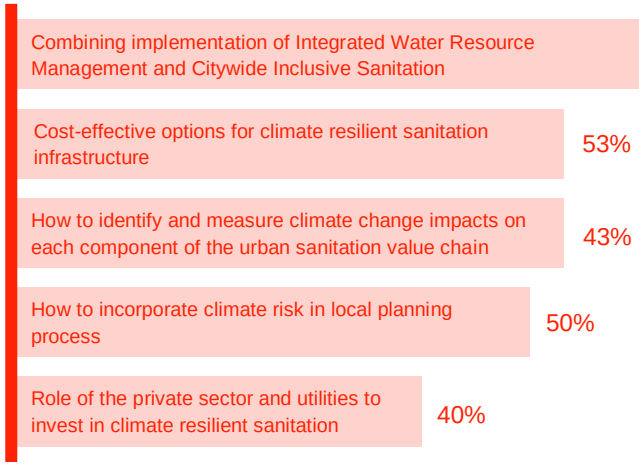
> *Interested to learn about linkages [of sanitation] to circular economy approaches and exploring financing options in this area.*

Infrastructure and service provision

Participants across the spectrum expressed an interest to build their skills to deliver Integrated Water Resource Management and Citywide Inclusive Sanitation, highlighting the direction towards a systems-level thinking (Figure 14). Cost-effective alternatives of sanitation infrastructure and technology in different climate scenarios along with guidelines on adaptive solutions emerged as other areas in need for technical assistance.

Training needs prioritised by in-country participants included identifying and measuring climate change impacts on the urban sanitation service chain, which can help in accounting for risk considerations in local planning processes. National and city level actors were also keen to develop skills on ways to engage and incentivize the private sector and utilities to invest in climate resilient sanitation options, and learn about best practices in cost-effective onsite sanitation solutions to protect groundwater contamination and support alternatives for people living above aquifers.

International actors expressed their interest to learn more about nature-based solutions and ways to measure and mitigate the impact of urban sanitation on climate change.



> *Would like to learn about developing adaptation indicators for sanitation and GHG accounting system for sanitation projects.*

Figure 14: Capacity building needs with regard to Infrastructure and service provision. Proportion of participants interested in capacity building on this topic (n=60).

User engagement

With regards to raising user awareness, participants were interested to learn about combining areas of traditional and technical knowledge to enhance resilience of urban sanitation systems at the community level (Figure 15). Other areas of capacity development included effective behaviour change communication and creating a market system for resilient sanitation products.

Figure 15: Capacity building needs with regard to User engagement. Proportion of participants interested in capacity building on this topic (n=60).

Capacity building interests of urban and climate actors

Most of the **urban actors** sought to receive training on financing and institutional capacity. Specifically, they were interested in resource mobilization including accessing finance to improve climate change adaptation action plans, financing for circular economy initiatives, and building local government capacity to plan and finance climate resilient urban sanitation. They were also keen to learn about how urban planning can contribute towards sanitation investments for all, city-level risk assessments for sanitation services, and participatory resilience planning that incorporates user experiences.

The top capacity building needs for the **climate actors** included metrics of success for climate resilient sanitation programming, tools and systems to account for emissions from sanitation projects, linking sanitation solutions to financial implications to establish a strong rationale for climate finance, and evidence base on traditional knowledge and nature-based solutions.

Consultations on sanitation with women in Indonesia.

7. Implications for the sector and ways forward

This section presents a set of multi-pronged strategies to respond to the findings presented in this landscape report. These are consolidated into four main actions, warranting attention from a breadth of different actors over the short and longer-term:

- ACTION 1: Engage with climate policy and better coordinate with urban resilience and other sectors
- ACTION 2: Evolve policy and shift practice to incorporate climate risks and resilience
- ACTION 3: Consolidate and continue to build the evidence base on climate resilient urban sanitation
- ACTION 4: Facilitate rapid learning and capacity building on key risks and adaptation responses

ACTION 1: Engage with climate policy and better coordinate with urban resilience and other sectors

1a) Increased attention to sanitation is needed in climate policy dialogue and mechanisms, through targeted engagement, ensuring that sanitation is given focus in NAPs and NDCs, and that these are followed through to increased resourcing and strengthened policy and programming

Conduct joint analysis and co-develop statements to take to COP27 and subsequent related meetings, ensuring sanitation is given due profile in the Water Pavilion and elsewhere, including making health-related arguments and reflecting IPCC 2022 findings, active engagement by the Alliance for Climate Change, WASH and Health and building on the multi-agency 'Call to Action on Climate Resilient Sanitation' led by UNICEF.

Build on existing engagement with the Green Climate Fund and ensure sanitation is kept prominent, and that it isn't subsumed by a focus on water. Develop and share evidence and arguments to support sanitation's role as a necessary ingredient for societal resilience and needed by those populations without adequate services, and support arguments for eligibility of financing to make climate vulnerable sanitation services adapt and increase resilience.

Further engage with key climate actors, including organisations working on the climate agenda and on the intersection of the climate agenda and water (e.g. Alliance for Global Water Adaptation and their tracker for NDCs). In doing so, shift framing from a focus only on sanitation to how sanitation can support other actor's imperatives and wider mitigation and resilience outcomes.

1b) There is general agreement that greater coordination and joint work across sanitation and urban resilience is needed, as well as strengthened coordination with other actors and sectors including agriculture, education and health

Two-way integration of skills and capacities through strengthened integration of expertise on sanitation, climate, hydrological and urban water cycle into urban planning and resilience processes, as well as strengthened urban planning and resilience expertise in urban sanitation programming. Bringing together sanitation and urban resilience actors is an important first step.

Informal settlements are an important initial focus for integration of climate, sanitation and urban resilience work, as climate change is likely to exacerbate existing vulnerabilities in these areas, including climate induced migration. Either as a component of this, or more broadly, urban housing may provide another important entry point.

Mutual benefits for sanitation and the agriculture sector in relation to climate change are possible and already well-established in arid countries, particularly in the Middle East and North Africa region in response to water scarcity. This area could benefit from further work, including measuring the contribution safe re-use can make to soil quality and to improve agricultural resilience through reliable water supply, e.g. safe practices to re-use wastewater for irrigation.

Actively participate in platforms and networks that exist outside of the sanitation sector, such as those used by urban planners and architects, local government associations, as well as climate actors, water resource managers etc.

ACTION 2: Evolve policy and shift practice to incorporate climate risks and resilience

2a) Existing citywide inclusive sanitation and other urban sanitation policy and programming needs to integrate climate risk considerations, strengthen evidence to convince policymakers to act and ensure local data collection that reveals risks and adaptation pathways.

Ensure sanitation policies and strategies incorporate climate resilience, draw on relevant data and risk assessments and develop relevant monitoring indicators. This includes a focus on '*data for decisions'* since adaptation response should be evidence-based, drawing on the many risk and vulnerability assessment approaches available and related hydrological and climate data. This will require service providers and cities to invest in relevant data systems.

Engage with existing implementing partners to action points made in this report, taking inspiration from the recent advances described in section 3 and elsewhere. Entry points include monitoring and quality assurance systems for climate resilience and safely managed infrastructure and services, and overall strengthened accountability of duty-bearers for on-going delivery of services, including in the face of climate change. Sanitation safety plans provide a further entry point, however need to be complemented by resilience thinking.

Activate utility networks (in locations where utilities handle sanitation, e.g. Vietnam) as an entry point for changes in practice by institutions with a sanitation mandate.

Influence development banks to ensure that climate adaptation and resilience is considered in institutional reform and complementary research and analysis is conducted alongside larger loans and infrastructure projects. Encourage experimentation with circular economy and nature-based solutions and green-blue infrastructure and collect evidence for how it works in practice.

Encourage donors to launch new funding opportunities in climate resilient urban sanitation programming (e.g. Dutch government, BMGF etc.) and pool resources, where appropriate.

2b) Incentivising implementers and researchers to work together is needed to generate robust and rapid evidence from current pilots, trials and experiences

Partnering implementers with researchers/consulting firms (e.g. multilateral development banks, private sector or non-governmental organisation implementers with academic researchers) through either implementation projects building in a research component, or researchers securing funding to work alongside implementers. Such approaches have shown promise to advance new practice and evidence, and ensure research is grounded and relevant. It also requires aligned timelines and expectations.

ACTION 3: Consolidate and continue to build the evidence base on climate resilient urban sanitation

3a) Strengthened coherent strategic thought leadership is needed to ensure alignment on key issues and to provide clarity and a credible, trusted voice that consolidates different viewpoints

Develop a series of briefs on key topics by leading thinkers and actors to work jointly on clarifying key tenets and concepts. E.g. these could include frameworks and metrics for resilience, frameworks to concurrently consider resilience and mitigation (clarifying trade-offs and synergies) and approaches to uncertainty and adaptive management.

Publish collaboratively in a well-respected journal, noting that there is already a piece soon on climate and WASH to be released as part of the Lancet inquiry, and other publications are possible and could act as seminal pieces that the sector can refer to.

Develop an updated scientific brief with an updated framework (moving from the framing of the Vision 2030 brief) that goes beyond technological resilience to consider resilience for sanitation in broader terms.

3b) There is a need to build the evidence base beyond technical aspects of climate impacts on sanitation infrastructure and there is interest to contribute to authoring articles, including from LMIC practitioners and researchers

Mobilise resources for special issue journals on urban sanitation and climate change, including support to LMIC contributors to take lead authorship. This could also involve setting up a mentorship program to support LMIC professionals and researchers to publish their experiences and work.

Advocate for funding on research on climate change and sanitation, particularly non-sewered sanitation as most research is on climate change and centralised sanitation services, hence both national research bodies and global donors need to prioritise this research agenda and the topics identified earlier in this landscape report (see Section 5.6) including on emissions as well as resilience.

ACTION 4: Facilitate rapid learning and capacity building on key risks and adaptation responses

4a) A set of leading countries and cities can be champions and demonstrations of key areas of effective practice to improve climate resilient sanitation

Confirm interested countries and cities with existing resources and interest to have their experiences highlighted and communicated to a broader set of actors, building on those who demonstrated leading practice in this landscape report or elsewhere. Consider cities and countries that span a breadth of climate issues (flood, drought, sea level rise etc.), and a focus on how practice differs from business as usual and 'proof of concept' of such practices.

4b) There is interest amongst sanitation, urban development and climate actors to engage in a community of practice on the topic of climate change and urban sanitation

Mobilise existing sector platforms and regional networks to engage networks and members on this topic. Such platforms include SuSanA, FSMA, IWA, CBSA, Toilet Board Coalition, SWA R&L constituency, utility associations, SNV D-groups, AMCOW, UNICEF regional offices and networks. These existing platforms can be utilised to share experiences and recent evidence on climate resilient urban sanitation. Consider how to engage wider stakeholders beyond implementers and researchers, such as utilities, service providers etc. and also how to bring additional climate and hydrological expertise into these platforms. Consider also how to garner the energy and commitment of youth amongst these networks and to support women's leadership.

Ensure inclusion of climate theme at upcoming events and include a focus on sanitation and climate change. Such events include UN Water 2023, FSM7-Abidjan (February 2023), Water and WASH Futures (February 2023), SACOSAN 2023 and other 2023-2024 events.

4c) Fast-track knowledge exchange across different contexts, given the imperative to act and learn rapidly as climate change impacts are already being felt

Facilitated exchange across countries and across cities, based on key topics identified in this landscape study (see Section 5.1) and evolving demand. Where resources are available, this would ideally include cross-visits between countries and cities, twinning could be an opportunity to share experiences of countries and cities leading practice. Consider differences between various urban typologies, taking into account city size. Linkages between national and local authorities are another important area to facilitate exchange.

Linking LMIC and HIC actors is an important imperative, as in HIC there are greater resources available to address climate resilience and a number of efforts underway. While major differences in sanitation technologies

(predominance of centralised sewerage rather than onsite and decentralised in LMIC) and institutional context (HIC have clearly mandated authorities versus common fragmentation of responsibilities in LMIC) may limit direct transferability, there are likely to be valuable exchange and support opportunities.

> 4d) There are common capacity building needs, and therefore opportunity for development of relevant short courses and curriculum to evolve the existing tertiary education on urban sanitation to meet demand

Mobilise efforts to develop and offer online courses on urban sanitation and climate change, with a focus on commonly demanded topics identified in this report (see Section 6). These could be co-developed by sector actors, as an opportunity to share experiences of champion and other countries and cities.

Upskill and engage with select tertiary institutions involved in teaching non-sewered sanitation (for instance including Global Sanitation Graduate School (GSGS) partners, building on existing IRC online courses) with a focus on institutions based in climate vulnerable countries and regions.

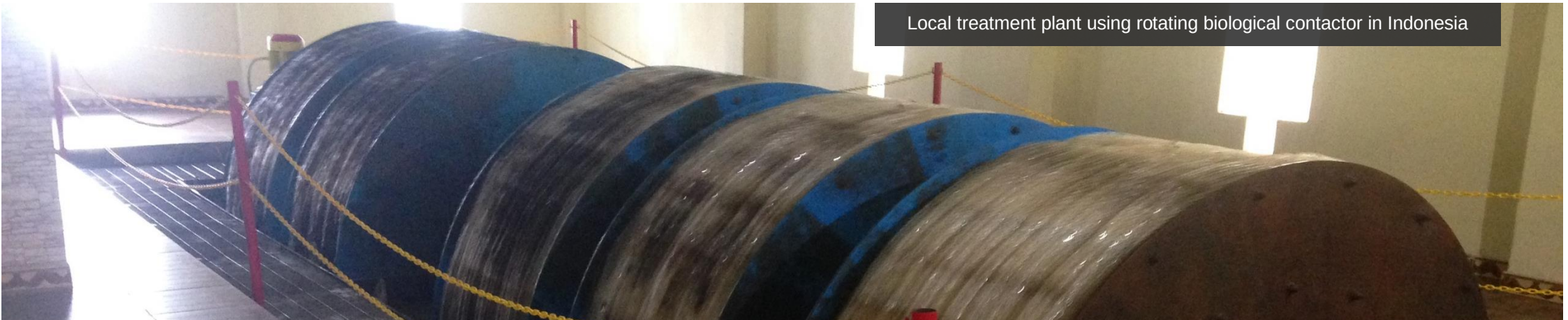
Strengthen internal training and capacity building mechanisms within international and local organisations to build common understanding and concerted actions on sanitation and climate resilience.

Harmonise capacity development approaches and tools to avoid a proliferation of uncoordinated material and directions, and building on existing sector tools (e.g. SFDs, FSM toolbox) where appropriate.

8. Conclusion

This report provides a view into the rapidly evolving area of urban sanitation and climate change. By highlighting the leading edge of current work, it offers insights to key strategies to accelerate action towards climate resilient urban sanitation. While long-term efforts are needed to shape the enabling environment to respond, there are immediate strategies that can be implemented to achieve initial wins. We can strengthen the argument to invest in this under resourced area, facilitate new partnerships with climate and urban actors and mobilise resources to scale up good practices and undertake relevant research. Action by both local and global actors can also advocate for attention to climate impacts on sanitation, trial new approaches and share knowledge and learning to increase the resilience of urban sanitation services and systems.

Going forward, all efforts to address urban sanitation must consider climate risks. With climate hazards becoming more frequent and intense in the near future, there is an both an opportunity and an obligation to act now to ensure that this crucial public service is given increased priority rather than being put at risk.



Local treatment plant using rotating biological contactor in Indonesia

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Annex 1

Relative prioritisation of evidence gaps by stakeholder group, average values on a scale of 0 (not a priority) to 3 (high priority).

Legend	⇓ In-country	⇔ International	◊ Grand total

	n = 9	n = 9	n = 23
Impacts and technological design of infrastructure	⇓	⇔	◊
What indicators can measure the climate resilience of sanitation infrastructure across varying climatic, geographic contexts?	2.8	2.0	2.4
What are the expected impacts or damage on urban sanitation infrastructure (onsite/offsite etc.) in different climatic contexts?	2.6	2.1	2.4
What lessons can we learn from urban sanitation infrastructure that was built without consideration of climate change?	2.4	1.9	2.2
What technologies are needed for different contexts and climatic conditions? (coastal, low-lying etc.)?	2.4	2.3	2.4
What is the role of nature-based on green-based solutions in adapting sanitation infrastructure and services to climate change?	1.7	2.1	2.0

	n = 8	n = 9	n = 22
Adaptation responses for infrastructure	⇓	⇔	◊
Examples of adaptation actions that improve sanitation infrastructure resilience and promote preventive solutions (rather than disaster response)?	2.8	2.3	2.5
How can mapping of sanitation facilities, infrastructure, service levels, climate hazards and other data be overlaid to inform planning processes?	2.6	2.8	2.7
What are successful and unsuccessful adaptation measures to support more resilient urban sanitation services?	2.5	2.4	2.5
What is the evidence of effectiveness of nature-based solutions in climate adaptation?	2.1	1.6	2.0
What type and level of redundancy should be built into sanitation systems to cope with climate hazards?	2.1	1.8	1.9

Note: Variation in number of respondents (e.g. n = 7 to 26) is the result of varied participation in prioritising evidence gaps by different groups of participants.

	n = 1 to 8	n = 6 to 13	n = 7 to 26
Financing	⇓	⇔	◊
What financial models for service providers can support sustainable provision in face of climate hazards, given user charges may be insufficient?	3.0	2.2	2.5
What are the financing costs for climate resilient sanitation in different climate contexts (urban, coastal, low-lying)? What is the additional cost?	2.9	2.5	2.5
How can local level disaster management budgets be mobilised and increased to support disaster response in sanitation?	2.2	1.6	1.9
Which other sectors have been successful in attracting climate financing (e.g. agriculture) and how could those strategies be used for sanitation?	1.9	2.2	2.1
What are the repair costs for sanitation facilities when damaged by different climate disasters?	1.0	1.8	1.7

	n = 1 to 6	n = 1 to 9	n = 2 to 21
Institutional arrangements and capacity	⇓	⇔	◊
What frameworks and information systems are needed to enable national level monitoring of climate impacts and resilience of urban sanitation?	3.0	2.0	2.5
At city level, what are the capacity building needs to incorporate climate risks into service planning?	2.8	2.3	2.4
How to mobilise and coordinate with local level disaster management in support of a better response for urban sanitation?	2.8	1.8	1.9
How can local evidence of climate change impacts be used to motivate and build the capacity of local government departments?	2.7	1.9	2.1
At country level, what are the capacity building needs to incorporate climate risks into policies?	2.5	2.1	2.2
How can we build institutional capacity to regularly monitor climate resilient service delivery at city level?	2.5	2.0	2.1
How to sensitise and enable service providers (e.g. masons etc.) to build climate resilient sanitation infrastructure?	2.0	2.0	2.0
How to shift local resource allocation from disaster response to preparedness and preventive action?	2.0	3.0	2.5

	n = 1 to 8	n = 6 to 13	n = 7 to 26
Coordination and integration	⇓	⇔	◊
What could the sanitation sector learn from other sectors (e.g. energy) on how to prioritise water and sanitation in the climate agenda?	2.8	2.1	2.3
What are case studies of successful institutional coordination, with different ministries working together for climate resilient urban sanitation?	2.4	1.9	2.2
How could cross-sectoral coordination of agriculture and wastewater sectors support mitigation solutions in urban sanitation (e.g. biogas)?	2.4	2.0	2.1
What are appropriate ways to integrate water supply, sanitation and drainage and how can this be done in practice and tailored to context?	2.0	2.5	2.4
How could city authorities share data on climate migrants and migration to enable services to be planned for these populations?	1.0	1.3	1.3

	n = 5 to 9	n = 4 to 7	n = 9 to 21
Service planning and providers	⇓	⇔	◊
What are successful business models of private sector participation in service delivery that incorporate climate considerations?	2.8	2.2	2.5
How can we create maps that overlay socio-economic information and sanitation services to consider equity in risk analysis?	2.6	2.0	2.6
How to facilitate access to climate data and climate scenarios at city-level to make informed decisions for service delivery?	2.6	2.7	2.7
What frameworks could support city-level risk assessments to inform planning of service delivery?	2.4	2.3	2.5
How can communications be provided to service provider on disaster preparedness and recovery (not just emergency response)?	2.1	2.3	2.3

	n = 7 to 9	n = 5 to 7	n = 12 to 21
Service delivery - impacts and responses	⇓	⇔	◊
What is the impact of different climate hazards on each part of the service chain?	2.6	2.1	2.5
If and how are current services coping with climate variability? How can this inform what it means to adapt to uncertainty of climate change?	2.1	2.0	0.8
What are the innovations in FSM service delivery that are adapted/resilient to climate impacts?	1.7	2.6	2.2
What tools and good practice can be shared on more effective translation of policy to on-the-ground implementation in climate resilient sanitation?	1.7	2.4	2.2
What are case studies of how cities are dealing with increasing intensity of flooding on sanitation infrastructure and services?	1.7	2.3	2.2

	n = 5 to 7	n = 4 to 9	n = 9 to 22
User engagement	⇓	⇔	◊
What strategies could overcome reluctance of users to adopt climate resilient sanitation?	2.8	2.5	2.7
What are experiences of different community members (women, people with disabilities, other vulnerable groups) of climate change impacts on sanitation services?	2.7	2.2	2.4
How to raise awareness among diverse users on climate change, it's impacts and the benefits of investing in climate resilient sanitation facilities?	2.7	1.8	2.0
How can an understanding of the costs of climate resilient sanitation infrastructure help users to make better decisions?	2.7	2.2	2.3
How are people's lives affected by climate change impact on sanitation, including the secondary impacts on livelihoods, health, migration etc.?	2.6	2.3	2.3

Note: Variation in number of respondents (e.g. n = 7 to 26) is the result of varied participation in prioritising evidence gaps by different groups of participants.

	n = 7	n = 13	n = 22
Monitoring, evaluation and learning	⇓	⇔	◊
How could M&E efforts in climate focused programming be improved so there is better capturing of successes and failures?	2.5	2.2	2.2
What framework and indicators should be used to monitor climate resilience of sanitation infrastructure and services?	2.5	2.2	2.3
How should JMP global monitoring be adjusted to take into account climate resilience?	2.5	2.1	2.2
How could an action research approach help us learn from implementation of adaptation responses in rapid learning cycles?	2.5	2.3	2.3
How can we evaluate the effectiveness of adaptation responses, considering a breadth of benefits (economic, public health, other benefits)?	2.4	2.4	2.4

	n = 1 to 7	n = 4 to 13	n = 5 to 26
Evidence to convince policy-makers	⇓	⇔	◊
What evidence is there of impacts of climate change on sanitation services (including the whole sanitation chain) that can support advocacy efforts?	2.9	2.2	2.3
What are the economic costs of damage to the sanitation service chain from climate hazards?	2.9	2.4	2.3
How can we quantify the benefits of considering climate change in designing sanitation systems and infrastructure?	2.6	2.4	2.5
What global. national and local data can be used to convince policy-makers to prioritise climate resilient sanitation?	2.1	2.2	2.2
What is the cost of inaction (to address climate change in urban sanitation)?	2.0	1.5	1.6

Note: Variation in number of respondents (e.g. n = 5 to 26) is the result of varied participation in prioritising evidence gaps by different groups of participants.

	n = 1 to 7	n = 4 to 13	n = 5 to 26
Analysis and experiences in policy and planning	⇓	⇔	◊
How is climate related urban migration impacting existing urban dwellers and their sanitation services?	3.0	1.5	1.8
What are best practices from different countries/cities on translating national policies to local implementation plans and regulations?	2.6	2.3	2.3
How many people have low sanitation service levels and frequent experience of climate hazards? (globally, nationally, locally)	2.6	1.7	2.2
How should disaster policies and processes incorporate damage to sanitation facilities and appropriately recognise the repair costs involved?	2.4	1.8	2.0
What are examples of successful advocacy efforts to incorporate climate change into sanitation policies?	2.1	1.7	2.0

	n = 1 to 7	n = 1 to 9	n = 2 to 22
Environment, water cycle and health	⇓	⇔	◊
How can we more holistically integrate the urban water cycle across water supply, drainage and sanitation, particularly wastewater and stormwater?	3.0	2.3	2.6
What is the scale and diversity of the public health impacts when sanitation systems are adversely affected by climate hazards?	2.7	2.2	2.3
How can water resources management policies and programs support more climate resilient urban sanitation?	2.6	2.3	2.4
How can both onsite systems and sewers be mapped to predict how pathogens and nutrients will be spread during flooding events?	2.3	1.7	1.9
What is the impact of flooding on pathogen transmission through drainage systems, groundwater and surface water and potential for human exposure?	2.0	2.0	2.0
What is the environmental impact of untreated faecal sludge or poorly managed FSM, in terms of both emissions and potential for contamination?	2.0	2.0	2.0
What learning from HICs on the circular economy (e.g. co-generation, co-digestion, regenerative design etc.) could be applied to LMIC contexts?	2.0	1.4	1.7
What are the opportunities and innovations in circular economy and green economy that utilities and cities could be trialling?	2.0	2.0	2.0
What is the place and role of container-based sanitation within climate resilient citywide inclusive sanitation (CWIS)?	1.9	1.9	1.9

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