

PERSPECTIVE OPEN



Sustainable sanitation and gaps in global climate policy and financing

Sarah Dickin¹✉, Moustafa Bayoumi², Ricard Giné³, Kim Andersson¹ and Alejandro Jiménez³

Although sanitation systems are fundamental for human health and sustainable development, limited focus has been placed on their contributions to climate mitigation and adaptation. Climate change threatens existing systems, as well as efforts to increase services for 2.3 billion people who lack even a basic sanitation service. At the same time, the sanitation and wastewater sector directly produces emissions associated with breakdown of organic matter, and treatment processes require large energy inputs. In light of these challenges, we describe gaps in how sanitation is being addressed in mitigation and adaptation, discuss how this results in little inclusion of sanitation in climate policy and financing at the global level, and implications of these gaps for different sanitation systems and geographic regions. Finally, we describe the need for planning frameworks to facilitate integration of climate change into sanitation policy and programming. This will be critical to increasing understanding of sanitation and climate change linkages among stakeholders, and more effectively including sanitation in climate action.

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INTRODUCTION

The Sustainable Development Goal (SDG) target 6.2 is achievement of universal access to a 'safely managed' sanitation facility and elimination of open defecation. The effort required to achieve this target is significant, as ~5.6 billion more people will need to use safely managed services, and ~1.3 billion will need to shift from open defecation to the use of a sanitation system by 2030¹. According to the Joint Monitoring Programme, 'safely managed' services refers to 'use of an improved type of sanitation facility that is not shared with other households and the excreta produced must either be safely treated in situ, or transported and treated off-site'². Closely linked is SDG target 6.3, which addresses the need for greater wastewater treatment, as the majority of wastewater is currently discharged untreated³.

Climate change impacts existing sanitation systems and impedes progress to achieving these targets by increasing variability in the water cycle, operating through increasingly intense climate events, unpredictability of water availability and decreasing water quality^{4,5}. These impacts also exacerbate existing challenges in the sector, such as sustainability concerns related to infrastructure breakdowns. Heavy precipitation and flood events can lead to physical damage of sanitation infrastructure, as well as indirect damages from flooding, such as impacts to transportation and energy supply that may disrupt regular operation and maintenance of systems⁶. In coastal areas, sea-level rise is also predicted to increase flooding⁷. Pit latrines and septic systems become non-functional when filled with water⁸. They may collapse or experience damage to the above-ground structures during flood or storm events making them unusable, with users forced to practice open defecation⁶. These events also impact collection and transportation systems for faecal sludge, particularly in densely populated urban areas and informal settlements.

Reduced precipitation and limited water availability impacts piped sewer systems, as these systems rely on adequate water to remove waste. Limited water availability due to drought can increase pollutant concentration resulting in more contaminated

wastewater, which has greater impacts when discharged untreated into the environment. In addition, high temperatures, heavy rainfall, flooding and drought events can modify the distribution of diarrhoeal diseases⁹. These sanitation-related health effects contribute to undermining gains made in public health over the last several decades¹⁰.

These wide-ranging impacts require careful consideration of adaptation options within the sector that are not limited to technical considerations. Increasing access to sanitation and wastewater treatment is also critical to consider from the perspective of climate mitigation where emissions are growing and have been overlooked. Despite the importance of climate change to the sanitation sector, there are gaps in how both mitigation and adaptation are being addressed. We describe these limitations, and ways that these gaps have resulted in little inclusion of sanitation climate policy, programming and financing.

Closing the sanitation gap while considering contributions to mitigation action

Sanitation and wastewater systems contribute to greenhouse-gas emissions (GHG) both directly through breakdown of excreta discharged into the environment or during treatment processes, and indirectly through the energy required for treatment steps. Most attention to emissions from sanitation and wastewater systems has been on centralised treatment plants, which require considerable energy input and are estimated to account for 3% of global electricity consumption. In addition, degradation of organic matter during wastewater treatment contributes ~1.57% of global GHG emissions and 5% of global non-carbon dioxide greenhouse-gas emissions^{11,12}. Although there is evidence that GHG emissions from biological processes in wastewater treatment plants are major GHG contributors in some countries, they remain poorly understood due to lack of the data availability and model complexity¹³. This information will be increasingly critical as countries move towards increasing coverage of wastewater treatment. For instance, in China, urbanisation and associated

¹Stockholm Environment Institute, Linnégatan 87D, 104 51 Stockholm, Sweden. ²Department of Earth Sciences, Uppsala University, Villavägen 16, SE-752 36 Uppsala, Sweden.

³Stockholm International Water Institute, Linnégatan 87A, Box 101 87, 100 55 Stockholm, Sweden. ✉email: sarah.dickin@sei.org

growth in the number of wastewater treatment plants has led to an increase in domestic wastewater emissions of 400% from 2000 to 2014¹⁴. In the case of GHG emissions modelled for the Metropolitan area of Santiago, Chile, these are projected to reach around 50% of national emissions by 2027 with increasing production and treatment of wastewater and sludge¹⁵. In addition to treatment processes, there is potential to reduce energy use in sewerage conveyance, such as through gravity-based systems and increased use of distributed or decentralised systems that reduce pumping distances¹⁶. As countries expand their wastewater systems and treatment capacities or replace ageing facilities, decisions made today will have long-lasting consequences for climate action.

Discharge of untreated waste into the environment and the use of on-site technologies, such as septic systems and pit latrines, are also sources of emissions but remain poorly quantified^{17,18}, despite the expected increases in access to these technologies promoted by SDG target 6.2. For example, ~80% of the global emissions of N₂O from human waste are from uncollected waste, a common occurrence in regions where the majority of the population is not connected to a sewage system with wastewater treatment¹⁹. The widespread use of pit latrines provides one example showing the importance of evaluating the GHG impacts of decentralised sanitation technologies. Pit latrines are one of the main sanitation options for low-income countries as they are hygienic, low-cost and easy to construct, and around 1.77 billion people rely on them on a daily basis²⁰. Pit latrines are estimated to account for ~1% of global anthropogenic methane emissions¹⁷. Although relatively small compared with other GHG sources, these emissions require consideration in planning of sanitation and wastewater systems. Providing sanitation access to 800 million people in India through pit latrines would cause increases in India's annual GHG emissions, equivalent to 7% of current levels²¹. The climate impact of providing 2.3 billion people who still lack access to basic sanitation with services such as pit latrines could more than double the GHG emissions from this source²². Pit latrines and similar on-site anaerobic technologies that produce methane are poorer choices from an emissions perspective than aerobic technologies, such as properly operated composting toilets^{17,23}. Additional measures to reduce GHG emissions resulting from the breakdown of excreta include regular emptying of septic tanks²⁴ and good wastewater management¹⁶. Despite these concerns, emissions are rarely considered by countries or development organisations in the selection of technologies to increase access and close the sanitation gap. In the context of rapid urbanisation and the need to scale up sanitation, research is needed to facilitate comparison of absolute and relative emissions of the available sanitation options to assist in future decisions on technologies²⁵.

In making progress towards SDG targets 6.2 and 6.3, there is significant potential to reduce emissions from sanitation and wastewater systems through recovery of energy and nutrients contained in waste¹¹, while also providing indirect reduction of emissions through renewable energy production and reduced dependency on fossil-based chemical fertilisers²⁶. This would contribute not only to climate action and reduced discharge of contaminants into the environment but also provide co-benefits through food and energy security. For instance, on a global scale, the phosphorus available from human excreta, if collected, could equal 22% of total global phosphorus demand²⁷. Substituting 5% of the existing nitrogen fertiliser production with nitrogen recovered from human waste would save more than 1.5% of China's annual electricity consumption²⁸. In addition, energy recovery from wastewater systems could provide over 55% of the electricity required for municipal wastewater treatment by 2040²⁹, demonstrating the dual benefits of reducing waste-related emissions and producing renewable energy.

Broadening understanding of adaptation action in the sanitation sector

Although climate impacts on sanitation systems present global risks, low-income countries face greater risks in many cases, however, attention to adaptation needs within the sanitation sector has been limited³⁰. To date, adaptation strategies have focused on 'additional' technical components of sanitation infrastructure related to particular risks that can be attributed to climate change³¹. Pit latrines can be constructed in a raised manner, using special coatings, or with smaller or shallower size of pits to improve ability to withstand flood events and reduce contamination in the case of collapse³². Ensuring separation of stormwater from wastewater is also promoted to reduce risks related to overflows or damage to collection and treatment infrastructure³³. In water scarce regions, water saving and reuse-oriented sanitation technologies with lower dependence on water supply are expected to have greater resilience⁸.

The focus on specific 'hard' adaptation measures to upgrade existing sanitation technologies has been reinforced by eligibility for climate finance, which has often been limited to these additional infrastructure elements. Such 'hard' components are more easily measurable as 'additional', while 'soft' measures are not so visible³⁴. As a result, technological solutions have been prioritised over 'soft' adaptation measures, such as improved planning, institutional and regulatory arrangements, capacity building, monitoring, public awareness or behavioural responses³¹. Rather than focus on additionality that privileges certain hard interventions, a greater focus should be placed on identifying the most efficient, effective and equitable adaptation measures within the sanitation sector, thus identifying measures with the lowest possible costs, most effective in reducing negative climate impacts, and that reach the most vulnerable populations and countries³⁵.

This requires greater consideration of soft adaptation strategies that go beyond technocratic responses³⁶. For instance, strengthening capacity of wastewater system managers to address climate change risks is needed to overcome knowledge gaps that may limit adaptation³⁷. Developing effective information systems can play a significant role in ensuring that sanitation workers and users can access updated and reliable data, which are needed to make informed decisions to ensure services are maintained. However, sanitation is often missed or excluded from detailed consideration in national assessments of climate change impacts, which hampers regular data collection and reporting³⁶.

The large gap in sanitation access demonstrates the importance of better integration of adaptation with development interventions. Poverty and underdevelopment are strongly interlinked with vulnerability to climate change³⁸, and essential services are a priority for reducing vulnerability³⁹. The IPCC Fifth Assessment Report (AR5) suggests that the most effective actions to reduce vulnerability in the short-term relate to the implementation of 'basic public health measures such as provision of clean water and sanitation... and alleviate poverty (very high confidence)¹³⁹'. This indicates a much broader role for essential services in climate adaptation, particularly among the most vulnerable, indicating that investments in basic sanitation infrastructure or behaviour change focused sanitation initiatives need to be promoted to shift 1 billion people from practising open defecation to more resilient services. Such interventions, however, are not commonly viewed as adaptation. This division between adaptation and development has limited mainstreaming of climate considerations into sanitation planning, which may be locking countries into vulnerable development paths.

The concept of adaptive development that promotes a greater focus on risk management in development is highly relevant for sanitation interventions³⁸. For instance, sanitation plays a fundamental role in adapting to altered incidence of waterborne

diseases, particularly diarrhoeal diseases⁹. Risks are greatest for those with the lowest levels of sanitation services. This is particularly critical during extreme events, although challenges in climate attribution may have limited stakeholder awareness of these risks^{40,41}. Sanitation interventions can also address structural inequalities contributing to inequal distribution of climate change vulnerability, as there is increasing focus in the sector on targeting countries and population groups in greatest need of assistance⁴². As inadequate sanitation disproportionately impacts women, poor and marginalised communities, and remote regions such as the Arctic⁴³, sanitation-related climate adaptation offers synergies in addressing inequalities. By building management of climate risks into sanitation development plans, adaptation action can make greater contributions to poverty alleviation and reduction of inequalities³⁴. As funds for addressing climate change are currently, and will continue to be, substantial in comparison to funds for sanitation investments, it is critical to consider sanitation within broader climate adaptation.

Sanitation missing from the climate policy debate

The range of mitigation and adaptation opportunities related to sanitation and wastewater systems indicate that opportunities for climate action are overlooked, as there is very limited inclusion in climate policy and finance. To understand where sanitation is situated in the climate policy debate, it is helpful to examine how it is included in the nationally determined contributions (NDCs). Although the NDCs are non-binding, they provide an indication of national priorities and interests of a contributing country related to mitigation and adaptation. Water is one of the top five sectors described as vulnerable to climate change within the NDCs, as it is identified by 100 countries⁴⁴. Despite this focus, limited concrete action has been proposed related to sanitation⁴⁵. The SDG–NDC connections tool analyses and quantifies the points of connection related to mitigation or adaptation activities included in the NDCs and the SDGs (at the level of goals and individual targets), including those related to access to safe sanitation and wastewater treatment⁴⁶. Our analysis of the SDG–NDC connections tool data, focusing on SDG 6-related NDCs, showed that only 2% of these NDCs deal with sanitation access, while wastewater management is mentioned in 3% (Fig. 1).

A further examination of the activities related to sanitation access and wastewater management shows a majority of the activities are adaptation activities, with few mitigation activities. Sanitation and domestic wastewater activities in the NDCs are reported largely by lower-middle-income countries, with very limited inclusion by high-income countries (Fig. 2a). Geographical trends can also be observed (Fig. 2b), as the Middle East and North Africa (MENA) region and Sub-Saharan Africa had the highest number of activities related to sanitation and wastewater. This may be due to extensive experience of water reuse and treatment in the MENA region, and the current water scarcity challenges facing both regions.

It is also notable that no sanitation-related mitigation activities are included by USA, Indonesia, India or China, despite these countries accounting for almost half of global recorded methane emissions from wastewater, and half of recorded nitrous oxide emissions from domestic wastewater in 2000⁴⁷. A limited inclusion of sanitation activities within the NDCs suggests that national decision-makers may not see a role for sanitation within climate action or have limited evidence of these linkages.

Is climate finance part of the problem or the solution?

The capital investments needed to meet the SDGs targets 6.1 and 6.2 for safe water and sanitation are approximately three times the current investment levels⁴⁸. These financing challenges highlight where current spending is insufficient to meet the SDG targets by 2030, but at the same time, it is important to consider how these investments will be made in ways that contribute to climate action. Climate finance offers an opportunity to address these investment needs through sanitation focused climate action; however, this has been very limited so far.

An analysis conducted by the authors of Approved Project Proposals by the Green Climate Fund (GCF) board up until April 1, 2019 indicates a limited number of projects focused on or related to sanitation and wastewater. Out of 99 projects approved so far by the GCF board, only 7 had a specific sanitation or wastewater element. Furthermore, these sanitation elements were mostly funded by development banks or national governments rather than the GCF itself. Excluding two projects that had no clear financial amount allocated for the sanitation component, the

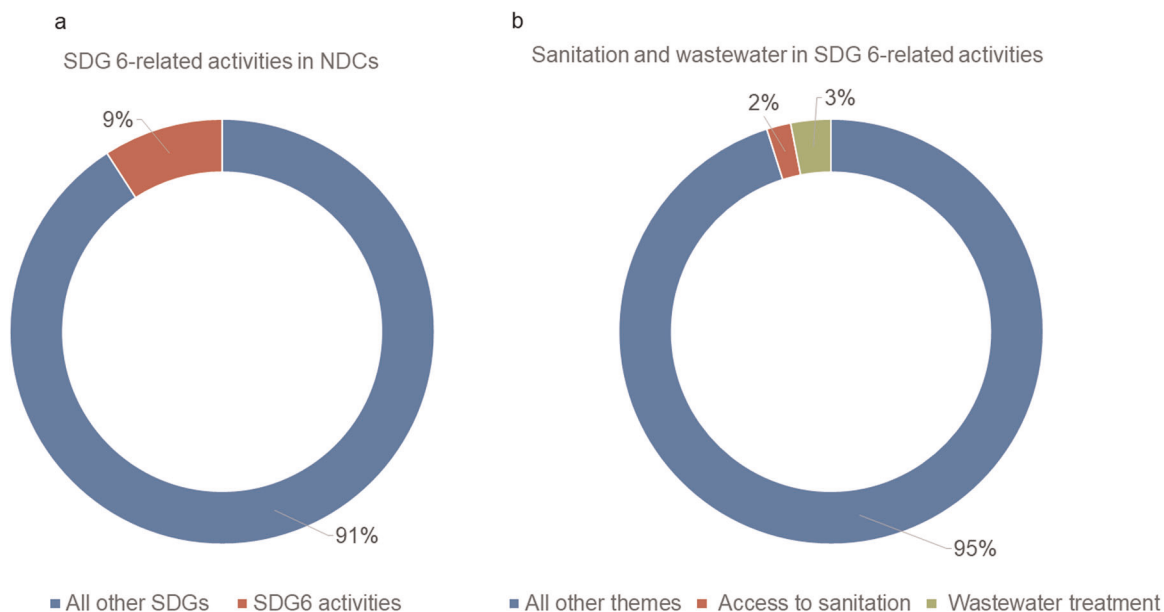


Fig. 1 NDC activities related to SDG 6. **a** The SDG–NDC connections tool indicates 630 out of 6900 activities (9%) were identified related to SDG 6. **b** Within the SDG 6-related activities, 2% were linked with access to sanitation and 3% to wastewater treatment⁴⁶. Other activities in SDG 6 relate to water management, water access and supply, improved irrigation.

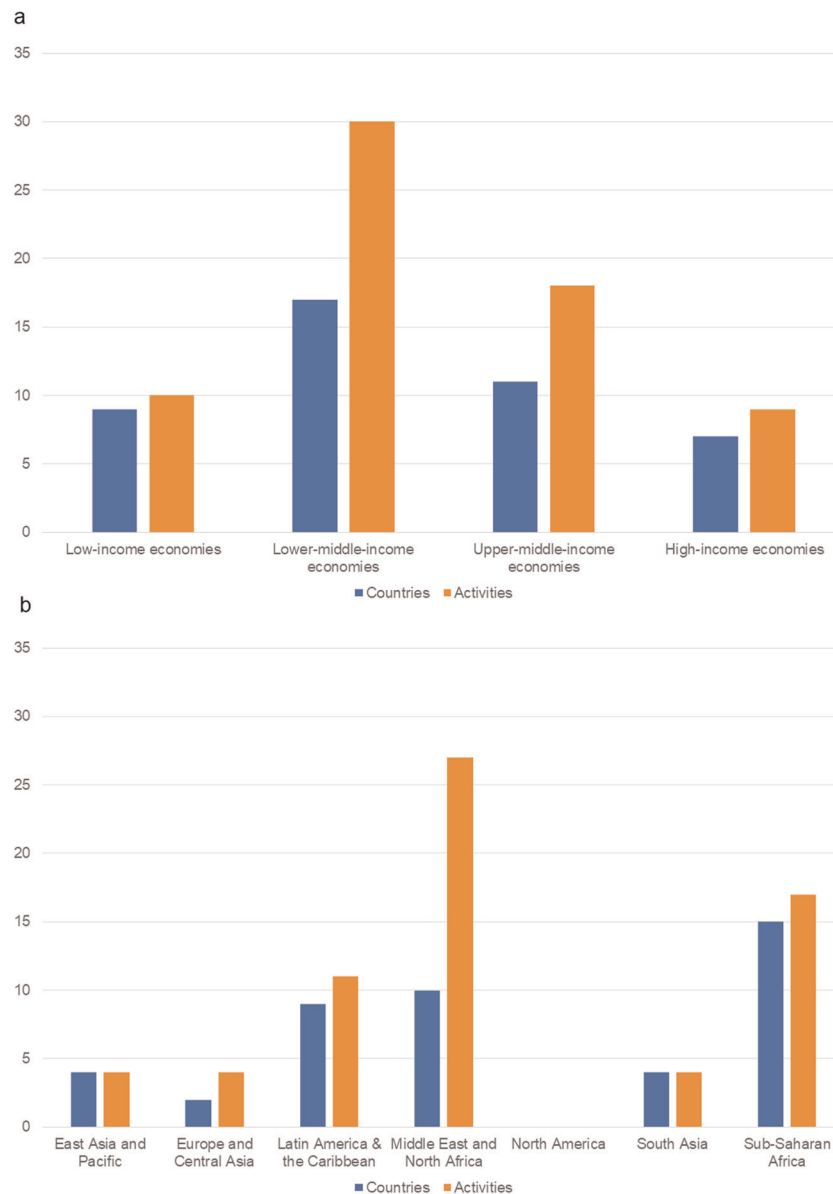


Fig. 2 Sanitation and wastewater activities included in the NDCs. a Displayed by World Bank country income classifications. **b** Displayed by region.

other five projects received USD 1.24 million from the GCF out of a USD 5 billion budget allocated to approved projects. This accounts for <0.025% of the GCF approved project budgets.

Examining climate-related Official Development Assistance (ODA) data from the OECD shows a similar trend. In 2017, projects related to water supply and sanitation with climate change as a main objective saw commitments of USD 938 million⁴⁹. In the same year, projects targeting mitigation and adaptation related to basic sanitation and large sanitation systems received USD 29 million. This represents 3% of climate-related finance for the water supply and sanitation sector. While there are other codes such as ‘Basic water supply and sanitation’ that also include sanitation projects, research has shown that there is a dilution of sanitation within drinking-water and sanitation ODA finance⁵⁰. This database is thought to reflect large overestimations, with far fewer projects than what is reported likely to be relevant to climate change mitigation and adaptation⁵¹.

Limited examples of climate finance related to sanitation indicate an overlooked source of funds for reaching SDG 6.2

and 6.3. Aside from the investments needed, there are large economic losses associated with unsafe water supply and sanitation, which are estimated to be 1.5% of global Gross Domestic Product (GDP)⁵². This number is even higher in certain regions where it exceeded 2% of total GDP in East Asian and Pacific and Sub-Saharan African economies, while in South Asia, it exceeded 4% of GDP⁵². With substantial economic co-benefits and an urgency to adapt to climate change while reducing emissions, there is a need to promote greater opportunities for climate finance to complement development finance in the sanitation sector.

This is especially important in least developed countries with high vulnerability to climate change impacts and limited adaptive capacity, while facing major sanitation challenges such as widespread open defecation. Such countries typically have a very small national budget to invest in sanitation. For example, Liberia has an open defecation rate of 62% in rural areas, and 20% in urban areas⁴², while wastewater treatment is not available in the country. The total average spending for WASH sector in the last

3 years is around 37 M USD/year, with government spending below 2 M USD/year⁵³. In comparison, a small-scale GCF project budget is above USD 10 million and up to USD 50 million, and a proposal to the GCF costs around USD 1 million to prepare⁵⁴. Such examples indicate that climate finance could make a major contribution to adaptive development in the sanitation sector; however, two obstacles are the investment and capacity needed to formulate projects, and the narrow focus on 'additional' sanitation components as adaptation measures.

Discussion and future directions

Sanitation has long been acknowledged as fundamental for health and well-being; however, its contributions to other aspects of sustainable development are more recently being recognised. The emphasis on integration throughout the SDG Agenda has highlighted that targets for sanitation and increased wastewater treatment must be achieved in order to attain a number of other outcomes, including good water quality, healthy aquatic ecosystems, gender equality and health and well-being⁵⁵. At the same time, contributions to climate action have been overlooked, limiting policy coherence with the SDG agenda and other global agreements that address systemic risks, particularly the Paris Agreement and the Sendai Framework on Disaster Risk Reduction. The Sendai Framework Target 4 focuses on 'Substantially reduce disaster damage to critical infrastructure and disruption of basic services,' which requires attention to sanitation systems. The limited inclusion of sanitation within the NDCs and climate finance indicates little awareness of the linkages between sanitation and climate change among stakeholders, and a need to strengthen this evidence in terms of impacts, as well as mitigation and adaptation opportunities. Assessment of climate change impacts on sanitation systems has focused on technical challenges, with a need for broader information on sanitation-related climate change impacts on social systems. This includes a more detailed understanding of the links between sanitation, health and climate change, including modifications of waterborne and vector-borne disease prevalence, increases in antimicrobial resistance and mental health and well-being implications, such as increased stress, potential exposure to violence and anxiety from lack of access to toilet facilities^{36,56}. A more comprehensive evidence-base will support planning of locally appropriate sanitation and wastewater systems that take into account a broader range of climate impacts. For development organisations, continued focus on 'business as usual' to meet immediate needs risks locking users into unsustainable systems in the face of future uncertainties¹⁶. Current choices for sanitation technologies will be strong determinants of sector emissions and climate resilience in the future³³.

More systematic assessment of GHG emissions from different sanitation technologies is needed to better inform decision-making in the sector^{13,23}, whether it involves selection of on-site technologies in low-income countries or upgrading of wastewater treatment plants in high-income countries. Moving from coarse estimates, such assessments must account for the role of context-specific factors, such as high water tables that increase the anaerobic zones of pit latrines, or the carbon intensity of an electricity grid that may drive interest in energy recovery from wastewater treatment^{17,57}. This evidence will inform the development and improvement of tools to support transition towards a more climate neutral water and sanitation sector. One such tool is the 'Energy Performance and Carbon Emissions Assessment and Monitoring' (ECAM) Tool developed by the Water and Wastewater Companies for Climate Mitigation (WaCCliM) project. The ECAM tool can assess carbon emissions for the urban water cycle, within the boundaries of utilities, in order to demonstrate how the sector can reduce greenhouse-gas emissions, both in the short-term (e.g.,

improving operational efficiency) and the long-term (e.g., reforming water infrastructure)⁵⁸. Similar tools could facilitate low-carbon sanitation development beyond the jurisdiction of water and wastewater utilities, e.g., for pit latrines and other on-site solutions.

A more comprehensive understanding of adaptation within the sanitation sector is needed, due to close links to poverty and vulnerability, which inextricably link it to development²⁵. Sanitation is a prime example of the need for a broader view of adaptation that considers the complexity of ensuring equitable access to essential services for the poorest communities while adapting to a range of climate change risks. Greater awareness of this connection is needed among stakeholders to facilitate more opportunities for sanitation-related climate finance, and particularly projects that ensure equitable access to sanitation through resilient and low emission systems. This includes better opportunities for adaptation in the short-term targeted to 'soft' activities, particularly easy-to-implement changes in practices, that reduce vulnerability and increase adaptive capacity³⁴. It is unclear whether the limited number of approved sanitation projects in the GCF portfolio is because climate finance organisations have been less likely to fund sanitation components, or whether countries have limited ability to apply for sanitation-related climate finance due to a lack of adequate capacity and context-specific evidence, but strategies to build greater awareness from both sides are needed. Considering the shortfall in current investment needed to achieve SDG 6.2, especially in least developed countries, climate finance can play an important role in narrowing the sanitation access gap and improving the resilience of current systems.

Moving forward guidance is needed to support decision-makers in systematically and effectively addressing the challenges increasingly presented by climate variability and change, identifying areas in need of further support and articulating costed and prioritised plans. Applying principles drawn from broader climate change literature has been proposed to inform sanitation planning, such as adaptive management, consideration of complex system dynamics and flexibility and diversified risk³¹. A framework that provides key principles for addressing WASH and climate change is the 'Strategic Framework for WASH Climate Resilience' developed by GWP and UNICEF. This framework seeks to advance sector thinking around WASH and climate change, focusing on the planning and execution of actions to promote climate resilience in WASH strategies, plans and approaches⁵⁹. A further opportunity is expanding the WHO Sanitation Safety Planning approach (SSP). SSP provides a structure to bring together actors to conduct local level assessment and management of health risks across the sanitation chain, which could be expanded to include climate considerations more comprehensively, beyond the identification of hazardous events related to seasonal or climatic factors. Similarly, adapting existing frameworks to address sanitation is an opportunity to draw on lessons from other sectors, such as the operational framework developed by WHO for building climate-resilient health systems⁶⁰. This approach focuses on identifying key health systems functions where climate resilience can be strengthened, in order to anticipate, prevent and manage climate-related health risks. These and other frameworks provide a good starting point, but more research is needed to adapt them specifically to a sanitation and climate focus, and to operationalise and evaluate the frameworks across different development contexts. In addition, planning frameworks require not only a focus on climate-resilient technologies, but addressing the limitations in mitigation and adaptation highlighted here, to ensure that sanitation effectively contributes to climate action.

DATA AVAILABILITY

The NDC–SDG connections data that support the findings of this study are available from <https://klimalog.die-gdi.de/ndc-sdg/>, which were obtained for this study and so are not publicly available. The data are, however, available from the authors upon reasonable request and with permission of SDG–NDC connections. The GCF data sets generated and analysed during this study are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

S.K.D., K.A., A.J. and R.G. conceived the paper. M.B. collected and analysed the data. S. K.D. wrote the first draft of the paper with development from R.G. and A.J. on adaptation and from K.A. and M.B. on mitigation. All authors commented on subsequent drafts and revisions.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Correspondence and requests for materials should be addressed to S.D.

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