Financing Water Supply and Sanitation in a Changing Climate

October 2020

Authors

Heather Cooley
Director of Research
Pacific Institute

Peter H. Gleick
President Emeritus
Pacific Institute

Jiehong Lou
Research Assistant
University of Maryland
School of Public Policy

Irving Mintzer
Research Professor
University of Maryland
School of Public Policy

Mai-Lan Ha
Senior Researcher
Pacific Institute

Sonali Abraham
Research Associate
Pacific Institute

Heather Arney
Senior Manager
Water.org

Heather Cooley, Peter H. Gleick, Jiehong Lou, Irving Mintzer, Mai-Lan Ha, Sonali Abraham, and Heather Arney. "Financing Water Supply and Sanitation in a Changing Climate," (October 2020). Pacific Institute and Water.org.

ISBN: 978-1-940148-10-6

Overview

Human-caused climate change is real and accelerating, creating new challenges for all aspects of freshwater management. Important gaps in our understanding of these challenges include both the complications climate change poses for planning, implementing, and sustaining water supply and sanitation (WSS) systems, especially for the poor; and the links between these systems and the emissions of greenhouse gases that worsen the overall climate problem. This paper addresses these gaps.

- **Section 1** examines the energy and greenhouse gas implications of expanding access to safely managed water and sanitation.
- **Section 2** presents current understanding of the climate impacts affecting water resources and built water systems and assesses these impacts in the context of specific WSS interventions.
- **Section 3** explores the effects of climate shocks on the ability to achieve Sustainable Development Goal (SDG) targets related to water for the world's poor (SDGs 6.1 and 6.2).
- **Section 4** evaluates opportunities for green finance and microfinance to reduce climate-related risk. Each section offers recommendations for making WSS systems more resilient to climate change and expanding access to critical funding.

Major findings of this assessment include:

- Water supply and sanitation (WSS) systems contribute to climate change through emissions of greenhouse gases (GHGs) from sanitation systems and from the energy used to power these systems.
- Rising temperatures and sea levels, changing precipitation patterns, and more frequent and intense floods and droughts are the key climate threats to the successful design, construction, and operation of WSS systems.
- The impacts of climate change on WSS systems may undermine progress toward achievement of SDG 6 by pushing communities "down" the ladder from safely managed to basic or even limited service and increasing the financial gap to meet SDG 6.
- Poorer and marginalized populations are especially vulnerable to climate impacts because of reliance on more vulnerable WSS systems, weaker institutional protections, and limited access to funding.
- Smart choices can benefit the climate and those living in poverty by adopting water and energy efficiency improvements that are affordable and resilient to changing climatic conditions.
- For water supply, changes in management strategies, such as protecting and diversifying sources and improving governance institutions, will often be more important than technology in improving climate resilience.
- For sanitation systems, the opposite is true: key vulnerabilities can be reduced by understanding the details of local climate risks — especially shortage and flooding risks — and choosing technologies less sensitive to these risks.
- Efforts to identify and mobilize new funding are critical to developing climate resilient WSS programs. Innovative new financing approaches are available, especially new forms of bonds (including "green" and "catastrophe" bonds), microfinance and microinsurance, and favorable taxing strategies.

"We conclude that water action must be part of climate action, or else it will be part of the problem. Universal water and sanitation access, as a promise, is inextricably tied to the climate future that our investments are building."

Section 1: Contribution of water supply and sanitation systems to climate change

Water supply and sanitation (WSS) systems contribute to climate change through direct and indirect emissions of greenhouse gases (GHGs). Direct emissions are from the breakdown of human excreta and food waste during wastewater management and depend on the technologies and management practices employed. Indirect emissions are related to the use of energy across the water-use cycle and are the largest source of GHG emissions from WSS systems.

This section addresses two research questions:

- What are the potential GHG implications of expanding universal access to safely managed water and sanitation?
- What strategies could be implemented to reduce those emissions?

Greenhouse gas implications of water and sanitation systems

There is growing interest in understanding — and quantifying — the water sector's use of energy and the related contribution to climate change. Although studies are limited and mostly focused on urban areas in developed countries, the available studies indicate significant temporal and spatial variability.[1, 2, 3] For example, one community may obtain water from a local source requiring very little treatment, while a nearby community may pump poor-quality water from a well requiring extensive treatment or rely on costly and energy-intensive seawater desalination. Likewise, a community may have multiple water sources with varying energy requirements, relying on nearby sources during wet years and importing water from distant sources during dry years.

Current energy use for WSS systems is estimated to be 120 million tons of oil equivalent (Mtoe), or 1.2 percent of total global energy production.[4] Energy use by WSS systems is projected to increase by 50 percent to 180 Mtoe by 2030 — without additional demands required to achieve SDG 6 — largely due to far greater use of energy-intensive desalination technologies in the Middle East, large-scale water-transfer projects like the South-North China Water project, and increased collection and treatment of wastewater.[5, 6] These studies, however, exclude the energy used in homes, businesses, and institutions to pump, heat, and treat water, and thus dramatically underestimate global energy usage for water.

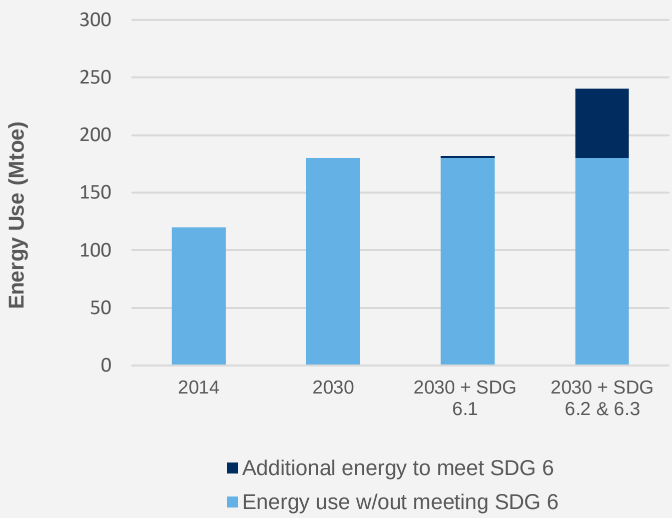
Providing universal access to safely managed sanitation, including halving the proportion of untreated wastewater, is projected to increase the total energy demand of WSS systems in 2030 by an additional 60 Mtoe (Figure 1). Additional energy needs for sanitation are largely in urban areas, as sanitation needs in rural areas would likely rely on more decentralized technologies and solutions that require no energy, such as pour-flush toilets and ventilated improved pit (VIP) latrines. Energy efficiency and energy recovery at new urban wastewater treatment plants could generate more energy than is needed, providing an opportunity to both sell the excess energy and reduce GHG emissions.

By contrast, providing universal access to safely managed drinking water is projected to increase 2030 energy demand by less than 2 Mtoe. This is because the additional water demand to meet modest basic needs of only 50 liters per person per day is relatively small, and the energy intensity of the solutions is low, especially in rural areas.

While global estimates suggest that providing access to water and sanitation will increase energy usage and GHG emissions, there are some circumstances under which the reverse would be true. For example, constructing a protected well with a hand pump that reduces reliance on water trucked from a distant source could save water and reduce GHG emissions. The actual energy and GHG implications of a given water and sanitation improvement depends on site-specific factors, including the form and level of energy used to meet water and sanitation needs and the technology or solution deployed.

[1] Plappally, A. K., and J. H. Lienhard V. 2012. "Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Disposal." Renewable and Sustainable Energy Reviews 16 (7): 4818–48. https://doi.org/10.1016/j.rser.2012.05.022.
[2] Cooley, Heather, and Robert Wilkinson. 2012. "Implications of Future Water Supply Sources for Energy Demand." Alexandria, Virginia: WateReuse Research Foundation. https://pacinst.org/wp-content/uploads/2013/02/report19.pdf.
[3] Klein, Gary. 2005. "California's Water – Energy Relationship." California Energy Commission. https://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.pdf.
[4] International Energy Agency (IEA). 2016. "Water-Energy Nexus." In World Energy Outlook 2016. World Energy Outlook. https://www.iea.org/publications/freepublications/publication/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf.
[5] International Energy Agency (IEA). 2018. "Energy, Water, and the Sustainable Development Goals." In World Energy Outlook 2018. Paris, France. https://webstore.iea.org/download/direct/2459.
[6] The South-North China Water project would divert 44.8 billion cubic meters of water per year from the Yangtze River in southern China to the Yellow River Basin in northern China.

Figure 1. Energy use for WSS systems in 2014 and 2030 with and without meeting SDGs 6.1, 6.2, and 6.3



Note: Light Blue indicates the total energy for current and projected WSS systems; Dark Blue indicates the additional energy required to fully meet SDGs 6.1 (water supply) as well as 6.2 and 6.3 (sanitation).

Source: Based on data in International Energy Agency (IEA). 2018. "Energy, Water, and the Sustainable Development Goals." In World Energy Outlook 2018. Paris, France.

Strategies to reduce water and energy demands and associated greenhouse gas emissions

The water sector can reduce the energy use and associated greenhouse gas (GHG) emissions from WSS systems through water-use efficiency improvements and reductions in water losses, energy-efficiency improvements, and adoption of renewable or lower-GHG energy options, including biogas recovery. These strategies could be implemented in a range of settings, from rural to highly urban.

As Box 1 on page 5 describes, strategies to save water often also save energy to collect, move, treat, and use water. Thus, improving water-use efficiency is a key strategy for reducing the energy requirements and associated GHG emissions of WSS systems. Water efficiency opportunities vary depending on the uses of water, as well as on the technologies and behavioral practices employed. Reductions in water losses are of particular interest in developing countries, where losses are estimated to exceed 35 percent on average,[7] and in regions with limited water supplies. Reductions in physical water losses saves both water and energy and reduces GHG emissions. They can also improve the financial viability of the utility, protect public health, and defer or eliminate expenditures for new supply and treatment infrastructure.

Energy-efficiency improvements can also reduce the energy use and associated GHG emissions of WSS systems. Relying on gravity to move water whenever possible is an effective strategy for eliminating energy requirements. Where pumping is required, sizing pumps appropriately and installing variable speed drives to match pumping capacity with pumping needs can help improve pump efficiency, as can replacing old, inefficient pumps with more efficient models. As the scenario in Box 1 describes, dropping groundwater levels from overuse can lead to substantial increases in energy demands (and depending on the form of energy used, increases in GHG emissions) for pumping. It is important to note that water for basic human needs is such a small part of total water demands that it plays no significant role in the groundwater overdraft occurring around the world.

Finally, programs to replace fossil fuels with renewables can provide significant reductions in GHG emissions. Energy requirements for urban and rural WSS systems can be met, in whole or in part, with renewable energy sources, including wind, solar radiation, biomass, and biofuels. As one example, the recoverable energy in domestic wastewater is far greater than is required to treat it, suggesting that sanitation systems could become a net generator of energy, rather than the large energy consumer it is today

.

[7] Kingdom, Bill, Roland Liemberger, and Philippe Marin. 2006. "The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries How the Private Sector Can Help: A Look at Performance-Based Service Contracting." The World Bank, 52.

Box 1: Saving water, saving energy: scenarios for India

Scenario 1: The Energy Costs of Groundwater Depletion
By 2050, the demand for water is expected to exceed supply. India is the largest user of ground water in the world, and an estimated 90% is used for irrigation purposes. Unsustainable groundwater use worldwide is leading to declining groundwater levels. This increases the energy required to pump water and potentially contributes to GHG emissions. Because groundwater is a key water source for India, strategies to use water more efficiently can reduce overdraft and save substantial amounts of energy. For every additional 10-meter drop in groundwater levels, the energy needed to pump India's groundwater would require more than four new 500 MWe powerplants, which could (depending on the type of energy used) lead to substantial additional GHG emissions. Strategies to address this problem include improving urban and agricultural water-use efficiency to reduce groundwater overdraft, improving the efficiency of groundwater pumps, using non-fossil fuel based energy sources for pumping, and adopting tariff policies that reflect the scarcity of water.

Scenario 2: Cutting leaks and unaccounted for water
Throughout the world, and especially in developing countries, substantial water is lost from urban water systems through leaks, theft, and other inefficiencies. In India, non-revenue water is estimated to be 42% of all water put into the distribution system. If only one-fifth of this water is recovered through leak detection and water loss control, enough water would be saved to meet the basic water needs of over 250 million people (at 50 liters per person per day). These water savings would be accompanied by substantial energy savings depending on where the water is sourced, and how it is treated and distributed.

Recommendations

Conduct localized assessments to reliably quantify the potential energy and GHG implications of water and sanitation improvements. Such assessments should (1) be based on local data due to significant variability in energy intensity of water and GHG intensity of energy; (2) include all stages of the water-use cycle, especially end-use energy; and (3) be prepared for each of the appropriate local WSS options under consideration.

Advance projects that reduce the energy — and associated greenhouse gas (GHG) emissions — from WSS systems. These include water efficiency improvements and water loss reductions; energy efficiency improvements; biogas recovery; and other renewable or lower-GHG energy options. Such investments would help to reduce the expected growth in GHG emissions associated with providing safely managed water and sanitation, and under some conditions, could even result in measurable reductions in GHG emissions.

Evaluate opportunities to bundle investments in water and sanitation improvements with investments in renewable energy and energy efficiency. As one example, the recoverable energy in domestic wastewater is far greater than is required to treat it, suggesting that sanitation systems could become a net generator of energy, rather than the large energy consumer it is today. Such investments would make WSS systems less vulnerable to climate impacts on energy systems and reduce GHG emissions.

Section 2: Potential impacts of climate change on water supply and sanitation systems

Climate changes will have direct and indirect impacts on WSS systems, and these impacts will grow over time. The key climate threats are increases in temperatures, changes in precipitation patterns and the frequency and intensity of extreme events, and rising sea levels. These climate changes will affect water availability, water quality, infrastructure operations, and the quality of WSS services. This, in turn, can result in increased water insecurity, greater rates of water-related infectious diseases, and higher costs.[8, 9, 10, 11]

A key challenge is that current WSS systems are designed and built for "stationary" or historical conditions. This is no longer appropriate. Climate change, by its very definition, requires a different statistical and management approach for evaluating and responding to dynamic weather conditions. Until recently, there has been little actionable information about the impacts of climate change for WSS systems and water has often been neglected in efforts to reduce the risks of natural disasters. The lack of detailed information about climate impacts makes decision-makers reluctant to integrate climate risks into planning.

This section addresses two major research questions:

- What are the key climate risks for water supply and sanitation systems?
- What are the key vulnerabilities of WSS systems?

Climate risks to water and sanitation systems

The key climate threats affecting WSS systems are rising temperatures, changing precipitation, rising sea levels, and changes in the frequency and intensity of extreme events, especially floods and droughts.[12, 13]

Rising temperatures: The most direct driver of climate impacts on WSS systems is rising atmospheric and oceanic temperatures. Higher temperatures will affect (1) water availability, particularly in regions that rely on glaciers and snowpack, and (2) rising demands for water by different human uses, particularly agriculture. The greatest vulnerabilities to temperature are in arid and semi-arid regions and where water use levels are close to the limits of available water supply, including in countries like Bangladesh, India, Ethiopia, and Kenya. Communities dependent on glacial melt or rivers that originate in mountainous regions, including the Himalayas, Andes, Alps, and Rocky Mountains, will be greatly affected.

Changes in precipitation: The most recent global assessments concluded with a high degree of agreement that "climate change is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions," worsening competition for water among human uses. Some such changes are already being observed around the world. The greatest vulnerabilities to changes in precipitation are in arid or semi-arid regions, as well as those regions dependent on rainfed agriculture; reliant on rainfall for short-term supply; and prone to flooding.

Floods: Climate projections and recent observations show an influence of climate change on specific regional floods. Floods are likely to become more frequent over time in some areas, including parts of South, Southeast, and Northeast Asia; tropical Africa; and South America. Current WSS systems are designed around specific historical flood statistics, and both increases and decreases can be problematic, causing damage, system failures, and forcing drinking water and sanitation systems offline for long periods. The greatest vulnerabilities to flooding are in urban areas with high stormwater flows and combined stormwater and wastewater systems; and in rural areas where populations live in or near floodplains. For informal settlements that lack adequate drainage/sewerage and depend on water kiosks and pit latrines, flooding is considered a higher risk than droughts.

---

[8] Bates, B., Z. W. Kundzewicz, S. Wu, and J. Palutikof. Climate Change and Water. Geneva: Intergovernmental Panel on Climate Change (IPCC), 2008. https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf.
[9] Bonsor, Helen C, Alan M MacDonald, and Roger C Calow. "Potential Impact of Climate Change on Improved and Unimproved Water Supplies in Africa." RSC Issues in Environmental Science and Technology 31 (2010): 25–50.
[10] Calow, Roger, Helen Bonsor, Lindsey Jones, Simon O'Meally, Alan MacDonald, and Nanki Kaur. "Climate Change, Water Resources, and WASH." Overseas Development Institute and the British Geological Survey, September 2011. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/7322.pdf.
[11] Charles, Katrina, Kathy Pond, Steve Pedley, Rifat Hossain, and Frederic Jacot-Guillarmond. "Vision 2030: The Resilience of Water Supply and Sanitation in the Face of Climate Change." World Health Organization, 2010. https://www.who.int/water_sanitation_health/publications/vision_2030_technology_projection_report.pdf.
[12] Bates, B., Z. W. Kundzewicz, S. Wu, and J. Palutikof. Climate Change and Water. Geneva: Intergovernmental Panel on Climate Change (IPCC), 2008. https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf.
[13] Bates, B., Z. W. Kundzewicz, S. Wu, and J. Palutikof. Climate Change and Water. Geneva: Intergovernmental Panel on Climate Change (IPCC), 2008. https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf.

Droughts: Droughts — a mismatch between the amount of water nature provides and the amount of water that humans and the environment demand — occur naturally and unpredictably, worldwide. In many places, droughts are likely to become more frequent and widespread with climate change, worsening the mismatch between water availability and water demand. More droughts will lead to falling groundwater tables, reduced surface water flows, drying of wells, increases in distances that must be travelled to collect water in rural areas (with subsequent adverse impacts on women, equity, and poverty), and increasing pollution of water sources. The greatest vulnerabilities to drought are in poor communities dependent on single water sources and major cities where total water demand is close to total water availability.

Sea-level rise: Sea-level rise is already occurring, will accelerate, and will reach levels that will cause massive destruction along coastal regions around the world. Sea-level rise will have two particularly severe consequences for WSS systems: (1) the destruction or contamination of currently secure natural water sources (both surface and groundwater) because of saline intrusion or actual flooding; and (2) the destruction of human-built water infrastructure, especially wastewater treatment plants built at or near sea level to facilitate the discharge of wastewater to the ocean. The greatest vulnerabilities include low-lying small islands and countries; regions with large populations near sea level; and communities dependent on coastal groundwater supplies vulnerable to saltwater intrusion, including countries like Bangladesh, Indonesia, and the Philippines.

Secondary effects from impacts on energy systems: Climate-induced disruptions of energy services will have indirect effects on WSS systems. The failure of energy systems can lead to the shutdown of water treatment and sewage treatment plants, failure of water-delivery systems, and contamination of urban piped water. In rural areas with minimal services, it can also lead to the failure of irrigation systems requiring energy inputs and the inability of community or household systems to pump or treat water. Another major impact will be higher costs for communities that use energy to provide WSS services, including for pumping, purification, and wastewater treatment.

Key vulnerabilities of water resources and water supply and sanitation systems to climate changes

Climate changes will affect both natural water resources and human-built WSS systems. Vulnerable natural water sources include all aspects of the hydrological cycle where water is provided or cleaned by standard hydrologic process of physical storage, water delivery, or biological cleaning. This includes aquifers, rivers, and lakes where water is withdrawn for human uses. The vulnerability or resilience of any WSS system may depend more on the quality of financial, technical, and management systems than on the specific type of system.

Surface supply systems: Most human needs for water are supplied from natural surface water supplies, like lakes and rivers, and the most significant vulnerability to climate changes will occur where these changes alter water availability in a way that exceeds human (or ecological) demands. Water-storage systems have traditionally been built to meet water-supply needs and improve a region's ability to manage both droughts and floods. Many regions have invested heavily in these systems, while other regions have underinvested in them. Where systems already exist, major investments may be needed to modify them to deal with climatic conditions substantially different from those for which they were designed. For regions still requiring such investments, new strategies to incorporate climate-resilience into design and construction are needed. Other climate-related risks for surface water systems include the possibility of increased rates of water-related diseases, such as malaria and schistosomiasis, or outbreaks of toxic algae, as temperatures rise.

Groundwater systems: One of the greatest overall weaknesses in water-resources management worldwide is the grossly inadequate knowledge of groundwater availability and use.[14] Because such important basic information is often missing, it should be no surprise that there remains substantial uncertainty about how changes in climate will affect different groundwater systems. Despite this, some conclusions can be offered. Both rising temperatures and changes in precipitation will alter groundwater recharge. Because temperatures are rising, in locations where precipitation stays the same or decreases, renewable groundwater supplies will decrease. Decreasing groundwater availability carries two key concerns: higher energy and economic costs for pumping from deeper and deeper wells; and the risk that shallow wells will dry up, eliminating access to some water supplies, especially for the poor unable to pay the costs of drilling deeper wells. Changes in the intensity of precipitation may both decrease groundwater recharge and increase surface flooding. Conversely, long-term increases in precipitation can increase renewable groundwater availability, but also carries the risk of increased contamination of groundwater systems from urban and industrial pollution. There is also high confidence that sea-level rise will worsen the risk of saline contamination of coastal groundwater resources.[15]

Water quality: Climate change threatens source water quality by altering the types and levels of contaminants and increasing treatment needs. Decreasing flows can increase concentrations of pollutants, while more extreme precipitation can increase the flow of nitrates and phosphates into surface and ground water systems. In regions where storm water and sewer systems are connected, there has long been concern about severe events that cause overflows and sewage spills. More extreme hydrologic events increase the risk of these spills.[16]

Human-built WSS systems: Climate change will have wide-ranging impacts on WSS systems. It is important to note that there are often conflicting and overlapping consequences for WSS systems. For example, where precipitation increases, especially in extreme events, overall water availability may improve but impacts on sanitation as a result of flooding are likely to be more severe for human and ecological health. Likewise, where the climate becomes drier, impacts on small-scale onsite sanitation systems may be positive by reducing groundwater pollution risks, lowering flood risks for pit systems, and limiting the spread of pathogens. Yet, drying can worsen access to safe and affordable water, and decreased surface water flows can worsen water quality.

Recommendations

Climate impact assessments and responses must be prepared at the regional level. To support efforts to reduce climate risks to WSS systems, country or site-specific assessments of climate vulnerability are needed, with priority given to those regions where needs are greatest and for those technologies and strategies with the greatest climate resilience.

Improving water management, governance, and institutions may be more cost-effective and successful than simply altering WSS technologies and infrastructure. Strategies include involving local communities and stakeholders in planning and management, including non-governmental organizations, utilities, and the private sector.

Ensure that new investments adequately incorporate climate risks. For example, investments in long-term water-supply systems dependent on coastal groundwater should assess and plan for protecting against salinity intrusion from rising sea level and alternative supply options in case of aquifer contamination. Small-scale sanitation systems should be designed to protect against floods.

Integrating climate risks early into WSS choices will help identify "no-regrets" strategies for improving service quality and health outcomes. For regions still needing water-supply investments, new strategies to incorporate climate resilience are needed. Where built water-supply systems are in place, major new investments may be required to modify them to deal with climatic conditions substantially different from those for which the infrastructure was originally designed.

---

[14] Moench, Marcus. "Groundwater: The Challenge of Monitoring and Management." In The World's Water 2004-2005, edited by P.H. Gleick, 2005:79–100. The Biennial Report on the World's Water. Washington D.C.: Island Press, 2004.
[15] Aslam, Rana Ammar, Sangam Shrestha, and Vishnu Prasad Pandey. "Groundwater Vulnerability to Climate Change: A Review of the Assessment Methodology." Science of the Total Environment 612 (2018): 853–75.
[16] Whitehead, P. G., Wilby, R. L., Battarbee, R. W., Kernan, M., & Wade, A. J. (2009). A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal*, *54*(1), 101–123. https://doi.org/10.1623/hysj.54.1.101

Section 3: Effect of climate shocks on achievement of Sustainable Development Goal 6 and vulnerable populations

Climate change — especially impacts on water availability, water quality, and water and sanitation infrastructure — will potentially undermine broad progress toward the SDGs and specifically SDG 6 and worsen poverty and current inequities in access to water and sanitation. Poorer, disadvantaged regions and communities are especially vulnerable to climate impacts. Climate resilience strategies can help to achieve better outcomes.

This section addresses two research questions:

- What will the impacts of climate change mean for the achievement of SDG6, particularly SDGs 6.1 and 6.2, and for vulnerable populations?
- Given the potential issues, what strategies can help build resiliency into systems to achieve better outcomes?

Climate change impacts on achievement of SDGs 6.1 and 6.2 and vulnerable populations

Climate change will have direct and indirect impacts on WSS systems, and these impacts may undermine progress toward achievement of SDGs 6.1 and 6.2 by pushing communities "down" the ladder from safely managed to basic or even limited service.[17, 18] For example, one criterion for safely managed water is that water is available when needed. Households whose primary water sources are no longer available due to shortage, contamination, or infrastructure failure may need to turn to water collection, and increased travel time to collect water could lead communities and countries to move down to basic or limited service. For sanitation systems, most of the direct impacts of climate change are associated with extreme events. Tables 1 and 2 summarize potential climate impacts on key criteria for safely managed water and sanitation, respectively.

Table 1. Climate impacts on safely managed water

Key criteria	Potential climate impacts
Improved services	Variable precipitation patterns, contamination, or infrastructure failure will affect which improved sources can be maintained.
Accessible on premises	Weather-related disasters may alter water availability for household systems (e.g., as dug wells and rainwater systems), resulting in increased reliance on off-site sources (tanker water, etc.) or a need to collect water off premises, potentially moving households from the "safely managed" to the "basic" category.
Available when needed	Households whose primary water sources are no longer available due to shortage, contamination, or infrastructure failure may need to turn to water collection. Potential increase in travel time could lead communities and countries to move down to basic or limited service.
Free from contamination	Major contamination risks to water sources possible due to flooding or from decreased rainfall and the ability of the system to flush itself of pollutants.
Affordability	Extreme weather events lead to disasters that require households to find alternative water sources (e.g., costly bottled or tanker water), thereby increasing costs and exacerbating affordability concerns.

[17] GWP, and UNICEF. "WASH Climate Resilient Development: Technical Brief: Local Participatory Water Supply and CLimate CHange Risk Assessment: Modified Water Safety Plans," 2014. https://www.unicef.org/wash/files/GWP_UNICEF_Tech_A_WEB.PDF.
[18] Programme Solidarite Eau (pS-Eau). 2018. "WASH Services and Climate Change: Impacts and Responses." Paris, France: Programme Solidarite Eau. https://www.pseau.org/outils/ouvrages/ps_eau_wash_services_climate_change_impacts_and_responses_2018.pdf.

Table 2. Climate impacts on safely managed sanitation

Key criteria	Climate impacts
Improved facilities	Impacts on facilities, including destruction or damage from extreme events, can prevent people from using improved services (due to lack of adequate water for flush toilets for example) and the need resort to open defecation.
Not shared	Major weather events may damage household sanitation systems resulting in the need to use shared facilities.
Wastewater treated offsite	Flooding may affect the safe and reliable operation of sewage systems; combined stormwater/wastewater systems can be overwhelmed by extreme events.
Safely disposed on-site	Extreme weather events affect on-site sanitation systems, such as flooding of latrine pits or disrupting septic tanks causing contamination. Extreme events also affect the transportation, treatment, disposal of onsite wastes.
Transported and treated offsite	Extreme weather affects the transportation and treatment systems leading to increased local contamination and increased public health risks.

Climate change will increase the investment needs for meeting SDGs 6.1 and 6.2, making their achievement even more difficult. According to the World Bank, meeting SDGs 6.1 and 6.2 requires an annual investment of $114 billion, excluding operation and maintenance costs.[19] This is approximately three times the historic spending on extending services to the underserved. Accurate estimates of the additional cost from climate changes are not available because climate impacts and the timing of these impacts are uncertain, the types of resilience strategies needed when and where are not known, and data are limited. Even in the absence of an accurate estimate, however, we know the investment gap is large and getting larger.

Women and children in developing economies, who already bear the brunt of obtaining and managing traditional WSS systems, will experience the worst additional complications from climate change. Poor and economically disadvantaged communities lack the financial resources to build or upgrade WSS systems in the face of climate change and lack the resilience to rebound from extreme events and climate impacts. And communities with limited access to safe WSS systems will suffer disproportionate health consequences from worsening climate impacts that adversely affect water quality and access to safe sanitation. In particular, the risk of water-related diseases such as cholera and dysentery rise as temperatures rise.[20]

Furthermore, changes in the climate will forcibly displace populations. As water supplies no longer meet demand or as communities are destroyed by climate-related catastrophic events, people will be displaced. Estimates vary, and are speculative, but some have suggested that hundreds of millions of people will be displaced by extreme storms, sea-level rise, and water scarcity by 2050 — for example, a drought in Niger in 1985 was estimated to have displaced a million people.[21, 22] People living in poverty will have very few choices and be forced to take refuge in displacement camps or overcrowded urban slums with inadequate, often non-existent, water and sanitation services.

We note with caution that interconnections and feedbacks among different options may improve one condition for one economic group while worsening conditions for another. For example, deep groundwater wells may be less vulnerable to climatic disruptions that alter groundwater levels, but such wells will be costly to dig and pumping water from such wells will increase the energy required to provide water. These adaptations will favor wealthier communities that can afford the increased costs.

---

[19] Hutton, Guy, and Mili Varughese. 2016. "The Costs of Meeting the 2030 Sustainable Development Goal Targets on Drinking Water, Sanitation, and Hygiene Summary Report." Water and Sanitation Program: World Bank Group. http://documents.worldbank.org/curated/en/415441467988938343/pdf/103171-PUB-Box394556B-PUBLIC-EPI-K8543-ADD-SERIES.pdf.
[20] Philipsborn, Rebecca, Sharia M Ahmed, Berry J Brosi, and Karen Levy. 2016. "Climatic Drivers of Diarrheagenic Escherichia Coli Incidence: A Systematic Review and Meta-Analysis." The Journal of Infectious Diseases 214 (1): 6–15.
[21] Berchin, Issa Ibrahim, Isabela Blasi Valduga, Jéssica Garcia, and José Baltazar Salgueirinho Osório de Andrade. "Climate Change and Forced Migrations: An Effort towards Recognizing Climate Refugees." Geoforum 84 (2017): 147–50.
[22] Gemenne, François. "Climate-Induced Population Displacements in a 4 C+ World." Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 369, no. 1934 (2011): 182–95.

Certain communities and populations at the bottom of the economic pyramid are especially vulnerable to climate impacts.

Climate resilient water supply and sanitation systems

Few water and sanitation technologies are resilient to climate change. **Changes in management strategies for water supply, such as protecting and diversifying sources, could be more important than technology in improving climate resilience. For sanitation systems, the opposite is true: key vulnerabilities can be reduced by understanding the details of local climate risks and choosing appropriate technologies less sensitive to these risks.**

Table 3 on page 12 provides key recommendations and actions for making water and sanitation improvements more climate resilient. Some observers recommend diversifying and decentralizing water sources to reduce the risk that the failure of any single source will not cripple a system, while others recommend consolidating and centralizing water management to improve efficiency of operations.

Recommendations

Work with planners at local and national levels to facilitate the integration of climate change into national water planning processes, including those related to meeting water and sanitation needs.

Support priority climate resilience strategies. Such strategies include extending urban water supply, sanitation, and drainage networks to unserved communities, together with a focus on improving their resilience to floods; diversifying and decentralizing water sources to reduce the risk that the failure of any single source will cripple a system; protecting exposed pipes and elevating key infrastructure from flood damage; and preparing for emergency water supply delivery, transportation disruptions, and disease outbreaks.

Avoid certain kinds of technologies or investments. For example, no new long-term centralized WSS infrastructure should be built near sea level without projecting and assessing sea-level rise risks. Reliance on shallow wells and shallow sanitation disposal system in regions vulnerable to flooding should also be limited.

Build water system reliance by improving local governance capabilities through institutional and technical cooperation; involving local communities and stakeholders in planning and management, including NGOs, utilities, and the private sector; and providing financial assistance from diverse sources to fund new projects, improve existing systems, and support operations and maintenance.

Table 3. Climate vulnerabilities of small-scale WSS improvements and key recommendations and actions.

Water improvement	Major climate vulnerabilities	Key recommendations/actions
Groundwater well w/hand pump	Changes in precipitation that alter groundwater levels and water availability; changes in groundwater quality	Protect groundwater from contamination with pads; reduce contamination sources. Shift to deeper, more protected aquifers; mechanize pumps.
Groundwater well w/electric pump (shallow well)	Changes in precipitation that alter groundwater levels and water availability; changes in energy needs or costs for pumping; changes in groundwater quality.	Shift to deeper, more protected aquifers; Protect groundwater from contamination with pads; reduce contamination sources.
Groundwater well w/electric pump (deep well)	Changes in precipitation that alter groundwater levels and water availability; changes in energy needs for pumping; changes in groundwater quality.	Build more energy-resilient systems to permit continued operation during extreme events.
Protected springs	Changes in precipitation that alter flow rates or volumes; changes in groundwater quality.	Expand short-term storage to improve resilience to drought; land-use protection for water quality.
Rain roof harvesting	Changes in precipitation that alter water available from rooftop systems; changes in energy needs for pumping.	Expand local storage for drought protection; diversify source availability.
Water filters/ treatment options	Treatment may become less effective or more costly if climate change alters contaminants.	Expand options for filtering/treating different contaminants.
Water tank or reservoir	Potential increase in water-related diseases; increased evaporation losses from reservoirs from higher temperatures; changes in precipitation may alter flood/drought risks.	Protect storage from contamination and extreme flooding events; expand storage volumes to increase resilience to droughts.
Sanitation improvement	**Major climate vulnerabilities**	**Key recommendations/actions**
Flush and pour flush toilet to septic tank or pit	Contamination or failure risk from flood events; possible changes in transporting/removing solids	Build systems to be flood resilient.
Ventilated improvement pit (VIP) latrine	Contamination or failure risk from flood events	Build systems to be flood resilient.
Composting toilet	Changes in temperature may alter effectiveness	Long-term changes in design may address this risk.

Section 4: Opportunities for climate finance in water supply and sanitation

Massive investments — far above what has currently been committed — are needed for WSS infrastructure and institutions, and the gap between need and commitment may be worsened as climate change accelerates. New financing strategies, including a range of innovative approaches to green financing, can help fill this gap, improve environmental services, and support national priorities in developing countries and communities. **Financing strategies applicable to climate mitigation and adaptation can be applied to improve access to WSS funding and smarter financing may be more important than smarter plumbing.** Assisting developing countries in improving WSS systems while simultaneously addressing adaptation and mitigation needs will create huge investment opportunities with many good jobs.

This section addresses the following question:

- How is green financing applicable to WSS?
- What are the opportunities for green financing and microinsurance to promote a low carbon emission sector or reduce risk for vulnerable households, increasing resilience?

Climate financing opportunities for WSS Systems

Minimizing the dangerous impacts from future climate change and producing stable, balanced, and sustainable economic development requires an all-out effort to shift the global economy onto a high-efficiency, low-carbon, and sustainable pathway. However, public capital will be insufficient to underwrite all the sustainable development projects and services that will be required to achieve the SDGs. Consequently, private sector investors will continue to play an important role in climate finance and serve as one of the major sources of investment capital for upgrading WSS systems.

Both the public and private sectors are helping to address climate change through new forms of investment. The Climate Policy Initiative estimates that average annual climate change investment is $579 billion, with more than half of this from private investments.[23] World leaders are working to make new funds available for climate finance, and under the Paris Agreement have committed $100 billion per year from public and private sources between 2020 and 2025.[24]

Green finance refers to "any financial instrument or investment — including equity, debt, grant, purchase and sale or risk management tool…in exchange for the delivery of positive environmental externalities that are real, verified and additional to business as usual."[25] Climate finance is one aspect of green finance. It focuses specifically on investments that mitigate GHG emissions or help communities adapt to the impacts of climate change by increasing funding available to public and private development projects. Funding support can come in the form of tariff support or carbon finance, or through improving a project's capital structure by reducing risk or the costs of debt and equity.

Several climate funds facilitate the provision of climate finance and serve the Kyoto Protocol and Paris Agreement. To date, the bulk of climate finance has been delivered through development banks, aid agencies, foundations, and a few commercial and private sector sources. In addition, multilateral institutions, such as the Global Environment Facility (GEF), Green Climate Fund (GCF) and the UNFCCC's Adaptation Fund, have directly funded climate change activities. However, these climate funds have so far provided only limited support for water and sanitation projects, "with millions of dollars delivered where billions are needed."[26]

An emerging set of promising climate finance approaches are emerging. For centralized, urban water systems, promising approaches include green bonds, results-based financing, as well as catastrophe and resilience bonds. However, the creditworthiness of small water-service providers or individual borrowers often does not meet the credit requirement of most commercial lenders. In addition, the small size of these project portfolios makes them harder to access capital markets, where there is a concern of investing in developing countries and emerging markets. Innovative financial instruments for small systems and individual borrowers include microfinance, microinsurance, and pooled bonds. Finally, there are several financing mechanisms seeking to establish proofs of concept, e.g., Green Climate Funds and Climate Finance Facilities. Each is discussed in more detail below.

[23] B. Buchner, A. Clark, A. Falconer, R. Macquarie, C. Meattle, and C. Wetherbee. 2019. Global Landscape of Climate Finance 2019. Climate Policy Initiative. https://climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2019/
[24] UNFCC. "Adoption of the Paris Agreement." Paris, France, December 12, 2015. https://assets.documentcloud.org/documents/2646274/Updated-l09r01.pdf.
[25] Climate Mundial. No date. What is Green Finance. http://climatemundial.com/whatisgreenfinance/
[26] Hedger, Merylyn. "Climate Change and Water: Finance Needs to Flood, Not Drip." Overseas Development Institute (ODI), October 2018. https://www.odi.org/publications/11220-climate-change-and-water-finance-needs-flood-not-drip.

Green bonds

Green bonds are recognized as low-carbon, climate-resilient investment opportunities by the United Nations. Since first entering the market in 2007, green bonds have seen strong growth, with green bond issuances reaching US$ 257.7 billion in 2019, a new global record. Water treatment and supply projects have dominated the US municipal green bond market, suggesting that green bonds are a promising financial instrument for WSS systems. Globally, however, the water sector accounts for just 4% of the value of the green bond market.

There are several examples of green bonds used specifically for WSS systems, including the $US 650 million in green bonds issued by the District of Columbia to support clean water projects. Likewise, Cape Town, South Africa issued a green bond in 2017 to upgrade reservoirs, treat dirty water to drinking level quality, and replace and upgrade sewers and pumps.[27]

Results-based financing

Results-based financing can be applied to improved management of water and forestry resources. The most relevant examples of using these bonds in the WSS sector are projects designed to reduce non-revenue water (NRW), which appears as a "loss" for the utility or water service company. NRW is the difference between the volume of water put into a water distribution system and the volume that is billed to end-users The benefits of using this approach are: (1) it encourages the private sector, as responsible investors, to invest in projects that address challenging social/environmental issues; (2) it transfers the risks of improving social and environmental impact to private-sector investors; (3) it allows the use of public funds more efficiently; and (4) it creates examples that can be scaled and replicated in other sectors and in many countries.

Catastrophe and resilience bonds

Catastrophe (Cat) bonds are a potential instrument that can help developing countries finance disaster risk management.[28] When a major catastrophe occurs, insurance companies have several options to mitigate some of the risks they face. These include transferring risks to a reinsurer through a reinsurance policy or passing the risk on to investors by issuing Cat bonds. With a Cat bond, the holder (i.e., the beneficiary) of the policy receives a pay-out when a disaster reaches a predetermined threshold, and investors lose part, or all, of the principal that they have invested. If no disaster exceeds the threshhold that triggers a payout, the investor receives the promised interest on his investment and the principal is returned at the close of the coverage period. In the future, Cat bonds may be engineered to cover multiple risks, including disruption of water infrastructure by extreme weather events, including hurricanes and flooding.

Resilience bonds are a type of Cat bond that can help public-sector entities access the global capital market while promoting investments in resilient infrastructure. These bonds have two principal components. The first component is an insurance structure that yields a resilience dividend when losses are avoided. The resilience dividend is achieved by integrating the impact from the resilient infrastructure with a reliable revenue stream to support implementation of the project. The innovation of resilience bonds is that they monetize the value of resilience that is achieved by an infrastructure project. This value is then transferred to a revenue stream, which creates further motivation for communities to invest in resilience. Communities that are particularly vulnerable to extreme weather events can be appropriate locations for issuing resilience bonds. The resilience bonds are designed to work in alignment with — and as a complement to — catastrophe bonds; however, no standard resilience bond framework has been accepted into the market.

[27] Todd Gartner, and John H. Matthews. "Forests and Wetlands Are Water Infrastructure. New Green Bond Helps Finance Their Protection." World Resources Institute (blog), May 22, 2018. https://www.wri.org/blog/2018/05/forests-and-wetlands-are-water-infrastructure-new-green-bond-helps-finance-their.

[28] Johannessen, Åse, Arno Rosemarin, Frank Thomalla, Åsa Gerger Swartling, Thor Axel Stenström, and Gregor Vulturius. 2014. "Strategies for Building Resilience to Hazards in Water, Sanitation and Hygiene (WASH) Systems: The Role of Public Private Partnerships." International Journal of Disaster Risk Reduction 10 (December): 102–15. https://doi.org/10.1016/j.ijdrr.2014.07.002.

Microfinance and microinsurance

Microfinance offers low-income households and small-scale providers of WSS services easy access to small loans for investment in WSS infrastructure, including the rehabilitation or expansion of small piped-water systems, new toilet solutions, etc. The fundamental mechanism of microfinance rests on the concept of a revolving fund. With this approach, a small initial injection of public funds can be recycled many times, creating very high degrees of leverage. In principle, revolving funds for microfinance applications can be scaled to cover large geographical areas. Although microfinance is an important financial tool for catalyzing private sector investment in WSS infrastructure, it can be strengthened to become a more powerful instrument. When paired with closely targeted government subsidies, microfinance programs can encourage scarce supplies of public funds to reach poorer communities and provide them with financial services that would otherwise remain inaccessible to them.

Microinsurance can serve as an innovative product that cushions millions of vulnerable low-income households and small-holder farmers from the financial shock of property loss, accidents, illness, and death. Microinsurance is defined as “the protection of low-income people against specific perils in exchange for regular premium payments proportionate to the likelihood and cost of the risk involved.”[29] The use of microinsurance to manage climate risk is less well-tested in the water sector but looks promising for regions facing imminent impacts from severe floods or droughts. One attractive strategy involves bundling of microinsurance products with services of high priority to the poor, such as health insurance or climate change insurance.

Pooled bonds

Pooled bonds function as special purpose vehicles to facilitate the efforts of small water-service providers to access capital markets and relieve budget pressure confronting these small service providers as they try to finance WSS infrastructure. Through pooled bonds, large volumes of capital can be mobilized, and transaction costs can be lowered through a single bond issuance. More importantly, they allow small or medium service providers, who individually lack the capacity to issue a municipal bond or to meet the funding requirements for gaining access to capital markets, to gain access to larger capital markets.

Green climate fund

The Infrastructure Development Company Limited of Bangladesh (IDCOL), is a financial institution wholly owned by the Government of Bangladesh and is an accredited entity of the Green Climate Fund. Today, IDCOL is exploring an innovative approach that would fund a project to replace and rehabilitate 320 km of piping in a water-distribution network, upgrade pumps, and rehabilitate other related infrastructure. The new system will provide access to clean water for over 25,000 residential and commercial customers and is financed using a mix of grants (50 percent), equity (15 percent), and debt (35 percent). This US$ 71 million project is part of a larger on-going surface water treatment project. A unique element of this project is that by fixing old, leaking water infrastructure, two revenue streams will be generated, one from the saved water and one from pumping new water.

Climate finance facilities

The Development Bank of Southern Africa’s (DBSA) Climate Finance Facility (CFF) is a specialized lending facility designed to increase private investment in climate-related infrastructure projects in the Southern African Development Community (SADC) region, which faces significant climate mitigation and adaptation challenges. The CFF will deploy capital to fill market gaps and crowd-in private investment, targeting projects that are commercially viable but cannot attract market-rate capital at scale from local commercial banks without credit enhancement. It represents the first time the “green bank” model has been applied to an emerging market. Green banks are public, quasi-public, or non-profit entities established specifically to facilitate private investment into low-carbon, climate-resilient infrastructure. This landmark facility offers significant proof-of-concept for middle- and low-income countries seeking to scale up the private investment required to meet commitments laid out under the Paris Agreement.

Finance facilities dedicated to WSS are well poised to attract climate finance that promote climate smart infrastructure and services. A recent blended finance tool initiated by Water.org and IFC, the Global Credit Enhancement Facility (GCEF), should provide interesting insights. This facility, launched in Fall 2019, will provide credit enhancement support structured as partial credit guarantees to local commercial banks to roll out new lending products for household water and sanitation.

[29] Churchill, Craig, ed. 2006. Protecting the Poor: A Microinsurance Compendium,. Vol. 1. International Labour Organization.

Recommendations

Initiate legal, regulatory, and taxing reforms at the national and local level to improve the enabling environment for domestic and international public and private capital investment. This can include engaging with the government to identify ways to channel corporate socially responsible (CSR) investment in the water sector to households and villages. For example, by moving the CSR contribution from a traditionally grant-based function to a strategic CSR investment fund, part of the CSR contributions could be used to provide credit enhancement.

Expand the scale and scope of microfinance and bundle microinsurance to reach more poor communities and households in remote areas. Microfinance and microinsurance are important financial tools for catalyzing private sector investment in WSS infrastructure but could be strengthened. For example, microfinance could be paired with targeted government subsidies. Likewise, microinsurance products could be bundled with high-priority services for the poor, such as health insurance or climate change insurance.

Work directly with water (and energy) utilities to improve water management and water delivery efficiency. This work could provide utilities with multiple benefits in terms of their liquidity, solvency, and business operation, thereby making them more credit-worthy and reducing their cost of capital. Climate mitigation funds may be appropriate for some WSS system improvements; for example, energy efficiency and energy recovery at new urban wastewater treatment plants could generate more energy than is needed, providing an opportunity to both sell the excess energy and reduce GHG emissions.

Apply innovative financing approaches to develop climate-resilient WSS systems. These include new forms of bonds (including green, catastrophe, and resilience. bonds), microfinance, microinsurance, results-based financing, favorable taxing strategies, and green climate funds and facilities. For example, resilience bonds could help urban water utilities reduce their financial vulnerability and capture the social benefits of resilient infrastructure projects. Likewise, results-based financing could be used to reduce water losses.

Support and help establish regional and national guidelines in developing countries that define green assets and prioritize investment in sectors in alignment with the Green Bond Principals (GBP). Regional GBPs, such as the Association of Southeast Asian Nations Green Bond Standards (ASEAN GBS), serve as a good example of mobilizing local efforts to propel the development of green bonds, enhance transparency and consistency of green transactions, and raise viability of green bonds in ASEAN countries.