Water.org: Meta-Study of Existing WSS Research

Thematic paper on Climate Change

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List of Abbreviations

GHG	Greenhouse Gas
MFI	Micro-Finance Institution
RAG	Red, Amber, Green
SDG	Sustainable Development Goal
ToC	Theory of Change
WASH	Water, Sanitation and Hygiene
WC	WaterCredit
WSS	Water Supply and Sanitation

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1. Introduction

1.1 Scope of the meta-study

The objectives of the Meta-study are "*to organize, synthesize and translate the (internal) evidence base into meaningful insights that compel action across donor and sector stakeholders*" and "*to inform Water.org's future research and learning agenda by identifying key evidence gaps where additional insights and research are needed*". These objectives reflect the breadth of the (internal) evidence that already exists and highlights where evidence between Water.org activities and outcomes related to these thematic areas remains weak. Recommendations are also made in terms of Water.org's future learning agenda as well as improving Water.org's programming to strengthen its potential contribution to the five thematic areas.

1.2 Climate change

The climate change component of this meta-study focused on the extent of the internal and external evidence base for two key themes:

- WaterCredit financed water supply and sanitation (WSS) improvements are more resilient to climate-related shocks and stresses.
- WaterCredit financed WSS improvements contribute to healthier environments and reduce climatic changes.

Resilience refers to "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change" (IPCC, 2007). Three sub-themes were investigated for the first key theme on the climate resilience of WaterCredit financed WSS improvements:

- **Resilient Water Supply and Sanitation Services:** Following WaterCredit, households access improved water supply and sanitation services more resilient to climate change than their pre-existing service.
- **Multiple Water Supply and Sanitation Services:** Following WaterCredit, households have increased resiliency to disruptions to WSS services resulting from climate change through having alternative household-level WSS solutions.
- **Water Supply and Sanitation Actors:** WaterCredit programs result in strengthened WSS actors at various levels. This includes households and partner MFIs with greater knowledge about the impacts of climate change as well as service providers, service authorities, and national governmental actors (i.e., ministries, regulators) more capable of adapting to – and mitigating the impacts of – climate change on WSS service provision.

One broad sub-theme was researched for the second key theme on the impact of improved WSS services on the environment and climatic changes. This focused on determining whether WaterCredit programs result in WSS improvements that use lower levels of greenhouse gas (GHG) emissions and are better for the local ecosystem than loan recipients' pre-existing service.

1.3 Methodology

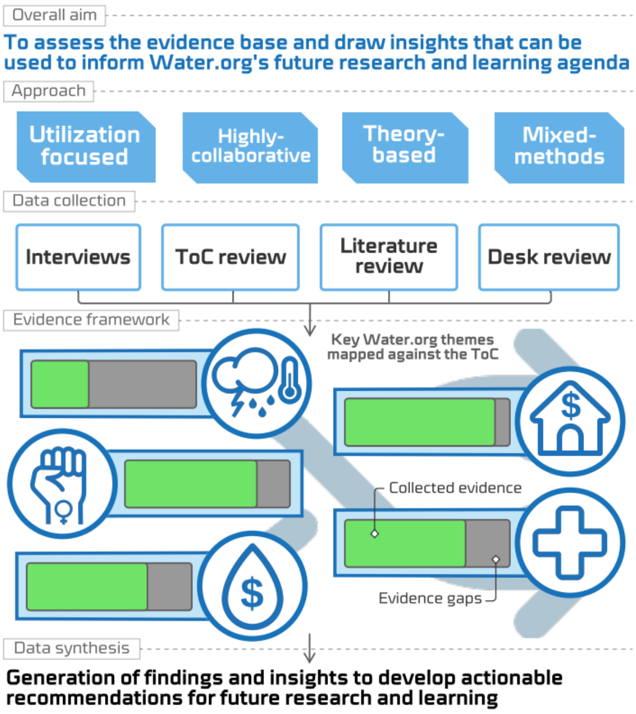
Figure 1 summarizes the approach and methodology applied for the meta study.

Six stages of work were carried out:

1. Review and reformulation of the thematic theories of change and development of a Theory of Action;

2. Deep dive document and data review for internal evidence. This incorporated a sense check with Water.org core team to identify whether any additional data was available;
3. External literature review to source evidence on associated sub-themes including any gaps identified with the internal evidence;
4. Drafting of the Thematic Paper;
5. Co-creation workshop to develop and refine the associated Theory of Change;
6. Finalizing the Thematic Paper.

Figure 1. Meta-study approach and methodology



Analysis framework: The reformulated theory of change and associated sub-themes was used as the analysis framework.

Internal evidence data sources: The meta study analyzed both primary (interviews with country program managers) and secondary data, quantitative (WaterPortal data and mwater data) as well as qualitative analysis (evaluation reports and other such publications).

External evidence data sources: External literature was sourced using Google Scholar, reference lists in sourced literature, personal libraries, and cross-over and sharing of literature from one thematic area search to another. Both internal and external evidence were entered into a data capture tool for further analysis.

Scoring the evidence: Each sub-theme is given a Red, Amber, Green (RAG) rating. A grey color block depicts that the rating is not applicable.

Table 1. Color classification of RAG rating

Internal data	Strong evidence	**External data**	Strong evidence
	Emerging evidence		Emerging evidence
	Mixed evidence		Mixed evidence
	Weak evidence		Weak evidence
	Not applicable		Not applicable

Internal quality control: in addition to the sense checking by Water.org, three discrete internal quality control steps have been taken: an internal workshop sharing the internal and external evidence to identify and discuss thematic findings and cross-cutting aspects; and 2 rounds of quality assurance of the report (draft and final).

Internal and external evidence: two icons are included in the text to denote whether a data source is internal to Water.org or external:

In = internal evidence   Ex = external evidence

1.4 Structure

The remainder of the report is structured as follows:

Section 2 provides a summary of findings.

Section 3 provides detailed findings for each of the sub-themes of (insert theme).

Section 4 provides a concluding statement.

Section 5 details the thematic Theory of Change (ToC).

Section 6 sets out a series of practical recommendations for consideration by Water.org.

References are then detailed.

2. Summary of findings

WaterCredit programs increase the climate resilience of WSS services – financed improvements are generally more climate-resilient than households' previous services.

The impact of climate change is felt on WSS services. The world's climate is rapidly changing, with many of the world's regions already experiencing warming of over 1.5°C above pre-industrial levels (IPCC, 2018). Climatic changes have various severe direct and indirect impacts on WSS service provision, including damage to infrastructure, deteriorating water quality, and reduced water availability. These impacts can potentially reduce progress towards SDG 6 and push households down the drinking water supply and sanitation service ladders.

Certain WSS services are generally more resilient than others under given climatic scenarios, and adaptions can be made to increase the resilience of WSS services. Maximizing the climate resilience of WSS infrastructure requires establishing how a technology option performs in the current climatic conditions and against projected climate-related future shocks and stresses. Some WSS services are generally more climate-resilient than others under broad climatic scenarios such as increased rainfall, increased high-intensity rainfall events, and decreased rainfall. For example, despite typically providing lower service levels, deep protected wells are widely seen to be more climate-resilient than piped water supply facilities under conditions of increased rainfall intensity and decreased rainfall.

WaterCredit programs result in households accessing WSS services more resilient to climate change. A comparison of households' previous WSS services and the WSS improvements financed through WaterCredit programs highlights that these improvements generally result in households accessing WSS services more resilient to existing weather events in their given country as well as projected climatic changes. Table 2 details several key findings in this area based on mWater data from India, Bangladesh, Indonesia, Cambodia, and The Philippines.

Table 2. Key findings – climate resilience of WSS infrastructure financed via WaterCredit programs

Water Supply Improvements	Sanitation Improvements
▪ Shift away from unimproved water sources such as open water sources and unprotected wells increases the resilience of water supply services under conditions of increased high-intensity rainfall and reduced rainfall. ▪ Many improvements are household connections to piped water supply services (43% of all WaterCredit loans). Despite typically providing higher service levels, this technology is often more vulnerable to high-intensity rainfall events – and to a lesser extent – low rainfall conditions than many other improved water supply services. ▪ Financed boreholes (34%) will often be the most climate-resilient water supply infrastructure under conditions of increased high-intensity rainfall and reduced rainfall, especially where these are deep boreholes.	▪ Considerable shift away from open defecation (previously practiced by 35% of WaterCredit WSS loan recipients) reduces vulnerabilities under conditions of increased high-intensity rainfall events because of the reduction in human excreta entering the environment during these events. ▪ Most improvements (55%) are toilets connected to septic tanks, which are deemed more resilient than sewers and pit latrines to conditions of increased high-intensity rainfall and reduced rainfall. ▪ Only a small percentage (9%) are toilets connected to sewers. Despite this technology option typically providing higher service levels, they are often associated with a comparatively high level of vulnerability to conditions of increased high-intensity rainfall and a moderate level of vulnerability to reduced rainfall. ▪ In some countries (i.e., India, Bangladesh), most improvements are pit latrines that have a very low level of resilience to conditions of increased high-intensity rainfall.

A variety of factors beyond the climate resilience of households' primary WSS services is crucial in determining the resilience of WSS services – Water.org lacks an internal evidence base on these areas.

Two further investigated areas are crucial in determining the climate resilience of WSS services. These were:

1. *Multiple Water Supply and Sanitation Services*. The ability to access WSS services with different levels of vulnerability to shocks and stresses decreases the possibility that all available WSS services become unusable during a single event. Diversifying risk in this way is even more important because of climate change as different WSS services often have varying levels of resilience to different climatic conditions. Water.org's very restricted evidence base on multiple-use WSS services indicates that WaterCredit programs have a comparatively limited impact on households' use of multiple water supply sources. However, this is an area warranting further investigating as it is a benefit of WaterCredit programs that can be expected.

2. *Water Supply and Sanitation Actors*. Actors at a variety of levels are crucial to ensuring the climate resilience of WSS services. This includes households and communities, service providers, service authorities (i.e., local government) and national governmental actors such as Ministries and regulators. These actors – and particularly service providers – are especially important in ensuring the climate resilience of water supply services. Water.org does not currently have sufficient internal datasets to draw insights on whether WaterCredit programs strengthen WSS actors' ability to perform their functions related to increasing the climate-resilience of WSS services.

Water supply and sanitation services contribute to climate change through GHG emissions; however, improved WSS services are critical to climate change mitigation and adaption and WSS services' GHG emissions can be reduced.

Water supply and sanitation services are responsible for a notable proportion of global energy production and GHG emissions. Energy use for WSS services were estimated to result in 120 million tons of oil equivalent (Mtoe) in 2014, equating to 1.2% of total global energy production. Even without considering the additional WSS services required to meet SDG 6, energy use by WSS services is projected to rise by 50% from 2014 levels to 180 million Mtoe in 2030. Moreover, sanitation services contribute to GHG emissions through the degradation of organic matter. Various factors impact the levels of GHG emissions from WSS services. Water.org understandably does not have data on these, preventing estimations on GHG emissions resulting from WaterCredit financed WSS improvements.

The GHG emissions from WSS services can be reduced. Efforts to limit GHG emissions globally cannot come at the cost of preventing or limiting progress ensuring universal access to safe and reliable WSS services. However, it is increasingly necessary to limit the impacts of existing and new WSS services concerning GHG emissions. Three primary strategies to reduce the GHG emissions from WSS services are: (i) improved water-use efficiency (i.e., reduction in non-revenue water and demand management); (ii) increased energy efficiency of WSS services; (iii) and switching from fossil fuels to renewable-based sources for WSS services.

Water supply and sanitation improvements can also have various positive and negative impacts on local ecosystems. These include direct impacts such as the over-abstraction of water sources and indirect effects such as reducing deforestation by limiting requirements for boiling water and aiding the development of a sense of stewardship to protect ecosystems and natural resources (Africa Biodiversity Collaborative Group, 2013). Water.org has comparatively limited data on environmental impacts from WaterCredit financed WSS improvements. Nevertheless, many WaterCredit programs lead to a shift away from open defecation, which reduces the harm to ecosystems through pathogens and nutrient overload, especially where these lead to in-situ disposal and treatment of human excreta.

Further research and ongoing monitoring are required to strengthen Water.org's evidence on climate change.

In

Water.org has a generally weak internal evidence base on climate change. Table 3 uses a simple traffic-light system to summarize the robustness of the internal and external evidence-base against each of the five sub-themes investigated in this thematic paper[1]. Overall, it highlights the relative weaknesses of Water.org's evidence base concerning the impact of WaterCredit programs on the resilience of WSS services and climatic changes. This largely reflects the fact that climate-related information has not been collected as part of Water.org's ongoing monitoring and WSS data collection activities and has not been a focus of most evaluations. The main exception here concerns the resilience of WSS services constructed through WaterCredit programs as existing data on the types of facilities constructed and households' previous WSS services can be paired with data on current and projected climate conditions to enable some broad inferences to be made.

Table 3. Robustness of the internal and external data for the six pathways for climate change

Sub-Theme	Internal Data	External Data
Resilient Water Supply and Sanitation Services		
Multiple Water Supply and Sanitation Services		
Water Supply and Sanitation Actors		
Greenhouse Gas Emissions and Environmental Impact		

Further improve Water.org's program monitoring survey. Water.org has taken important steps in its program monitoring survey tool to begin periodically collecting information relating to climate change; however, further measures are required to ensure Water.org has a robust evidence-base in this area. Nevertheless, additional improvements are required to the survey to further investigate the impact of WaterCredit programs on the climate resilience of households' WSS services. Key areas for further questions concern whether climate change influenced the WSS improvement made, whether household sensitization activities included climate change issues, and whether households' water supply improvement has enabled them to access multiple water supply sources.

Recommendation: **Expand on the aspects of the program monitoring survey focused on climate change.** Water.org should develop further questions included in the survey, with key areas requiring further questions or more detailed questions including whether climate change influenced the decision to finance the WSS improvement and the type of improvement selected, household sensitization activities, and multiple water supply sources.

Water.org partners MFIs need to provide more data related to climate change. Water.org partners are currently not required to provide ongoing data on key aspects related to climate change. For example, whether WSS improvements are being tailored or modified to address climatic issues. In many cases, this direct data from partner MFIs would be the most efficient means to expand Water.org internal evidence-base on this increasingly important topic.

Recommendation: **Expand the areas that Water.org partner MFIs report ongoing data on to include key climate change aspects, especially in regions particularly affected.** This should include areas such as WSS improvements tailored or modified to address climatic issues in their operational,

[1] The traffic light system utilized is as follows: (i) green = strong evidence; (ii) light green = emerging evidence; (iii) orange = mixed evidence; and (iv) red = weak evidence.

how climate change is integrated into trainings, and (where applicable) the service providers managing WSS services.

One-off research activities focused on climate change will remain important. Water.org has conducted research activities on climate change. These one-off research activities will remain important moving forwards as not all key information required to determine the impact of WaterCredit projects in this area can be ascertained through household surveys or information provided by partner MFIs.

Recommendation: **Conduct one-off research activities on climate change.** Conduct periodic or one-off research activities to establish the impact of WaterCredit programs in relation to specific aspects of climate change that cannot be assessed through regular monitoring and evaluation activities. Potential areas to be focused on in these research studies include the climate resilience of WaterCredit financed WSS improvements, the energy-use and GHG emissions of WSS improvements, and the operations and management of WSS services.

3. Findings

3.1 Impacts of climate change on WSS service provision

The direct and indirect impacts of climate change are already undermining WSS service provision.

The world's climate is rapidly changing. Most of the world is experiencing rising temperatures – 20-40% of the global population living in regions that have already witnessed warming of over 1.5°C and global temperature increases of at least 2°C are projected by 2100 (IPCC, 2018). Global warming results in the increased frequency of flooding, droughts, and other extreme weather events – over 90% of the 1,000 most severe disasters since 1990 were water-related disasters (Aguaconsult, 2021). The frequency and intensity of extreme weather events will continue rising (IPCC, 2018).

Climatic changes have severe direct and indirect impacts on WSS services. The direct impacts of climate change on WSS services are primarily felt through the water cycle. This includes short-term hazards (shocks) such as flash flooding or storm surges as well as slow on-set threats (stresses) like droughts and water scarcity or deteriorating water quality. Of these direct threats, flooding is the most prevalent climate change-related threat to WSS infrastructure (WaterAid, 2021). Climate change also indirectly impacts WSS service provision. For example, through the weakening of the energy systems required to run many WSS services and accelerating demographic changes (i.e., rapid urbanization) that place greater pressure on often already strained WSS services and service providers.

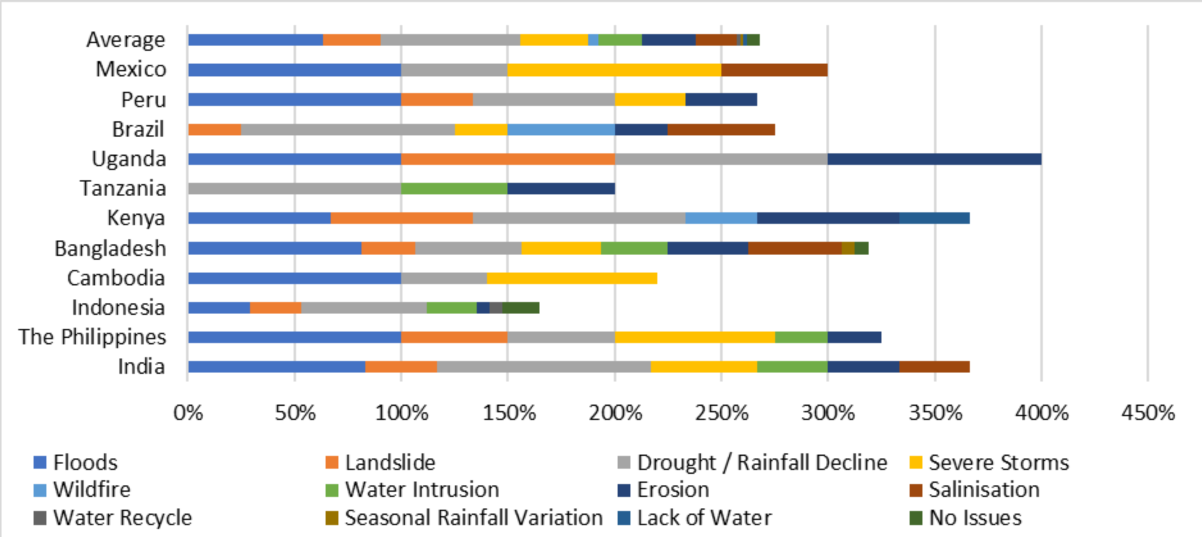
Climatic changes undermine WSS service provision, impeding progress towards Sustainable Development Goal (SDG) 6. The direct and indirect impacts of climate change are being felt on WSS service provision – Table 4 details key impacts of climate change on the WSS services households receive. These impacts will reduce progress towards SDG 6, preventing some households from achieving first-time access to improved WSS services and pushing others down the drinking water supply and sanitation service ladders. For example, service disruptions to WSS services are expected for up to 13% of the population in the most vulnerable countries because of flooding (WaterAid, 2021). Additionally, 27% of the global population currently lives in potentially severely water-scarce areas – this is predicted to rise to 42-95% by 2050 (WaterAid, 2021).

Table 4. Impacts of climate change on WSS services (Pacific Institute, 2019)

Impacts of Climate Change	
Safely Managed Water Supply	**Safely Managed Sanitation**
▪ Variable precipitation patterns, contamination, or infrastructure failure will undermine the proper **operations and maintenance** of improved sources. ▪ Decreased **accessibility** to water **on-premises** as reduced water availability can heighten reliance on off-site sources. ▪ Households turn to **unimproved water sources** or spend increased time collecting water because of infrastructure failure, contamination, or water shortage at their primary water source. ▪ Increased **contamination** of water sources (i.e., fecal contamination, saltwater intrusion). ▪ **Unaffordability** of costly alternative water sources (bottled or tanker water) households may rely on following extreme weather events.	▪ Destruction or damage of facilities can prevent people from using improved services and the need to resort to **unimproved** or **shared** sanitation. ▪ Flooding or water scarcity can impede the safe and reliable operation of **sewage systems**. ▪ Extreme weather events affect **off-site transportation and treatment systems**, leading to infrastructure failure and increased local contamination and public health risks. ▪ Extreme weather events affect **on-site sanitation systems** (i.e., flooding latrine pits) and the transportation, treatment, and disposal of on-site wastes.

Water.org partners for WaterCredit programs report that they and their customers are experiencing a range of climate change-related issues. Figure 2 presents the different climate-related issues that Water.org partners report that they and their customers are currently experiencing. These issues naturally vary from country to country.[2] Nevertheless, drought / rainfall decline (65%), floods (64%), severe storms (32%), landslides (27%), erosion (25%), water intrusion (20%), and salinization (19%) were the most cited climate issues.

Figure 2. What type of climate issues do you or your clients experience now? (Climate change partner survey, Water.org)



Climate change impacts Water.org partners – the effects of climate change are both positive and negative. Figure 3 is based on a Climate Change Partner Survey undertaken by Water.org and details the level of concern that Water.org partners have regarding climate change. It highlights that most partners view climate change as either 'some concern' (48%) or a 'major concern' (42%), with only a small percentage 'not concerned' by climate change.

Figure 3. To what degree is climate change a concern or threat for your business, client and / or communities in which you operate (now or in the near future)? (Climate change partner survey, Water.org)

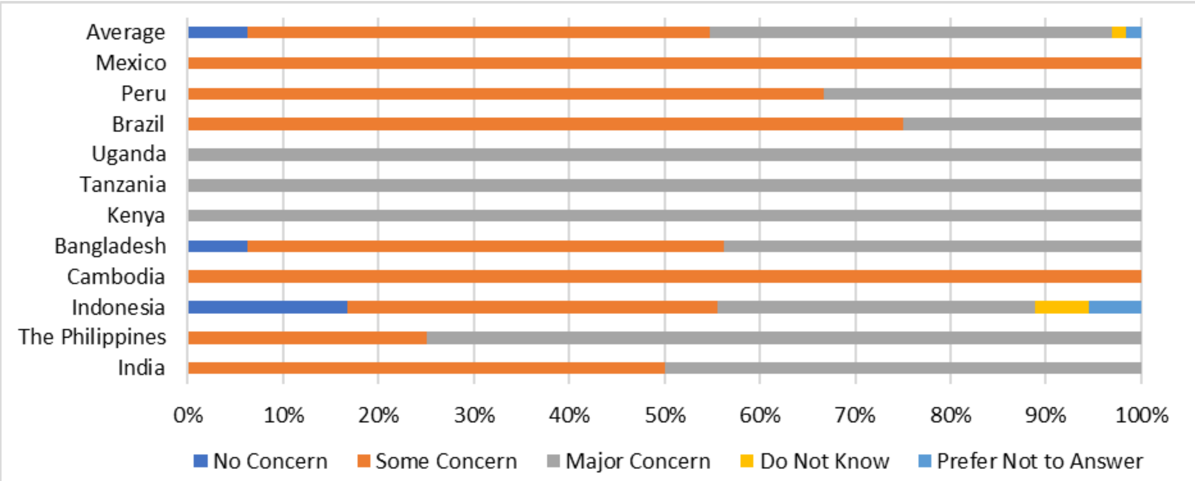


Figure 4 presents findings from the Climate Change Partner Survey concerning how climate change is affecting the business operations of Water.org partners.[3] In the first instance, it reaffirms that most Water.org partner MFIs are impacted by climate change – just seven percent of respondents reported 'no effect'. Of the three impacts of climate change that Water.org partner MFIs could select from, the most commonly cited was the greater risk of customers not repaying loans on time due to the

[2] Percentages are added on top of one another as Water.org partners were able to pick multiple climate issues.
[3] Ibid.

economic effects of climate change (65%). This was followed by changes in product demand (33%) and changes to the population of their customer base (28%).

Figure 4. How is climate change (now or in the near-future) affecting your business operations? (Climate change partner survey, Water.org)

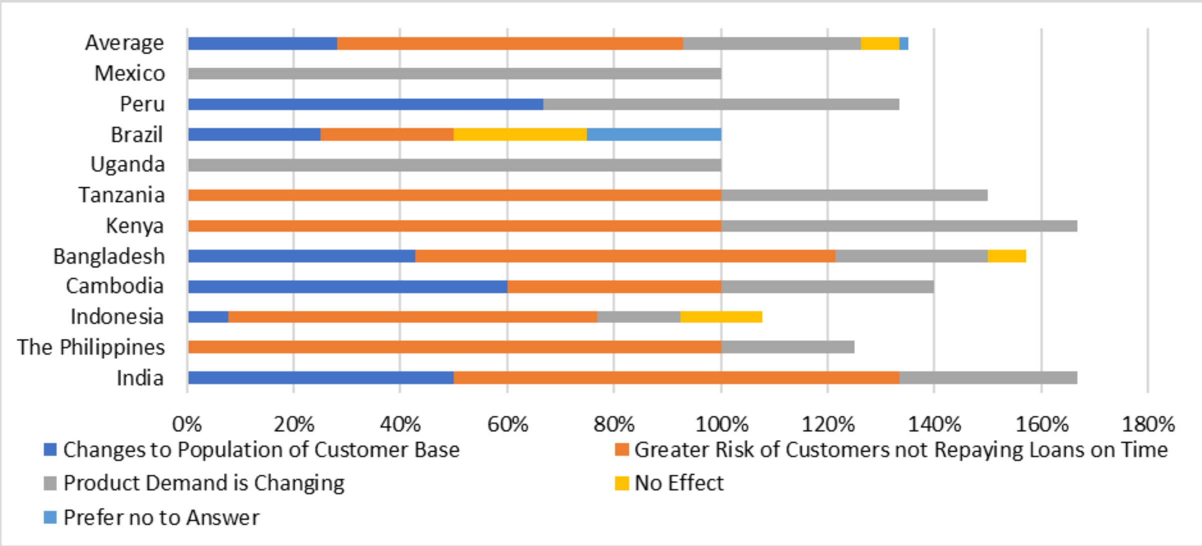
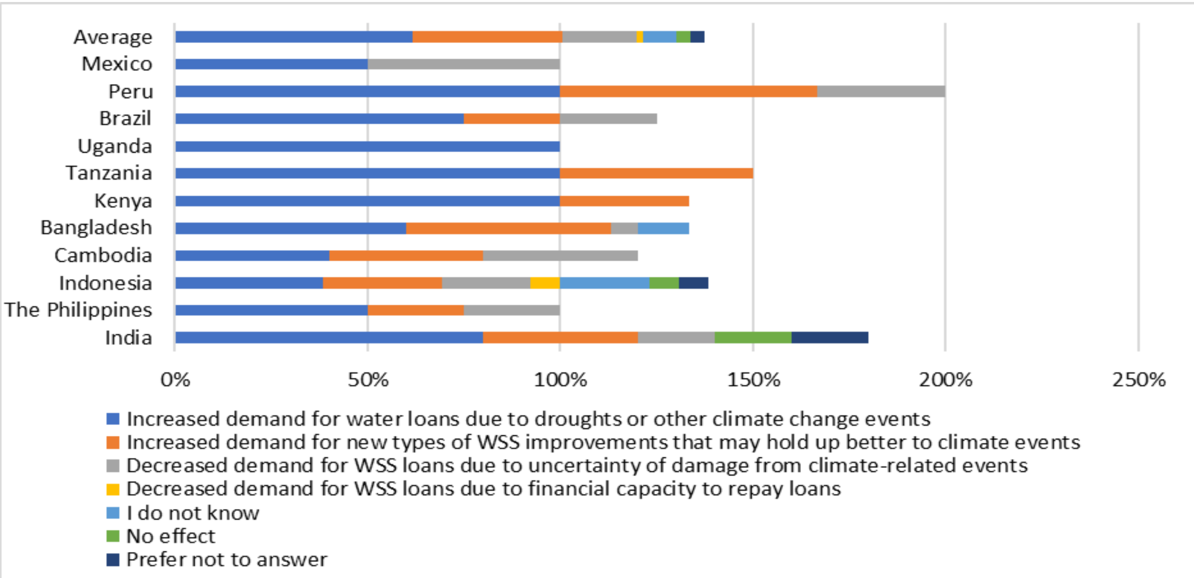


Figure 5 details findings from the Climate Change Partner Survey regarding how climate change is affecting the clients of Water.org partners regarding their demand for WSS services.[4] It highlights that climate change is largely perceived to positively impact clients' demand for WSS services. 62% of Water.org partners reported that climate change resulted in increased demand for water loans due to droughts or other climate change events, while 39% stated that there was increased demand for WSS improvements that may hold up better to climate change-related events. Conversely, 19% of Water.org partners noted that climate change had decreased demand for WSS loans due to uncertainty of infrastructure damage from climate-related events.

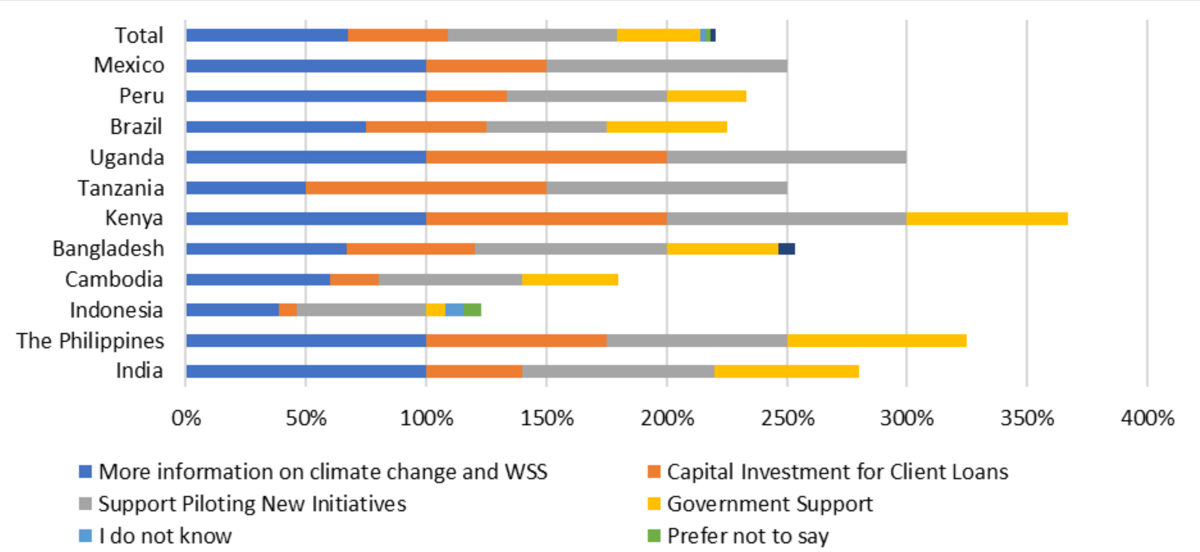
Figure 5. How is climate change (now or in the future) affecting your clients and their communities' demand for water and / or sanitation services? (Climate change partner survey, Water.org)



[4] Percentages are added on top of one another as Water.org partners were able to pick multiple climate issues. This figure only factors in respondents that viewed as being of 'some concern' or a 'major concern'.

Water.org partners require various forms of support to address threats posed by climate change. Figure 6 details the results of the Partner Climate Change Survey concerning the support Water.org partners believe they need to better address the impacts of climate change on WSS services in their programming. [5] It highlights that the most commonly cited support requirements were Water.org assistance piloting new climate change related initiatives (71%) and more information on climate change and WSS (68%). This is followed by capital investment for client loans (41%) and government support (34%). Only two percent of respondents stated that they did not require support.

Figure 6. If climate change is or may be threatening your operations and customers, what would you need to better understand in order to address those threats? (Climate change partner survey, Water.org)



The climate resilience of WSS service provision can be increased. Resilience refers to "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change" (IPCC, 2007). Various measures can strengthen the climate resilience of WSS services. The following three sub-sections present the available external and internal evidence on key pathways through which WaterCredit programs could increase the resilience of WSS service provision:

1. Resilient WSS services.
2. Multiple WSS services.
3. Strengthened WSS actors.

3.2 Resilient water supply and sanitation services

Table 5. RAG rating for evidence of resilient water supply and sanitation services

Internal data	▪ Water.org has very limited detailed data on the climate resilience of WSS improvements financed through WaterCredit programs. This is not an area that Water.org has systematically collected data on.	**External data**	▪ Certain WSS services are generally more resilient under given climatic scenarios. ▪ The size, level of centralization, and energy requirements of WSS facilities are all important factors in determining their climate resilience. ▪ Technology adaptions and infrastructure selection are especially important for increasing the climate resilience of sanitation facilities. ▪ Most sanitation facilities are not resilient under conditions of increased high-intensity rainfall

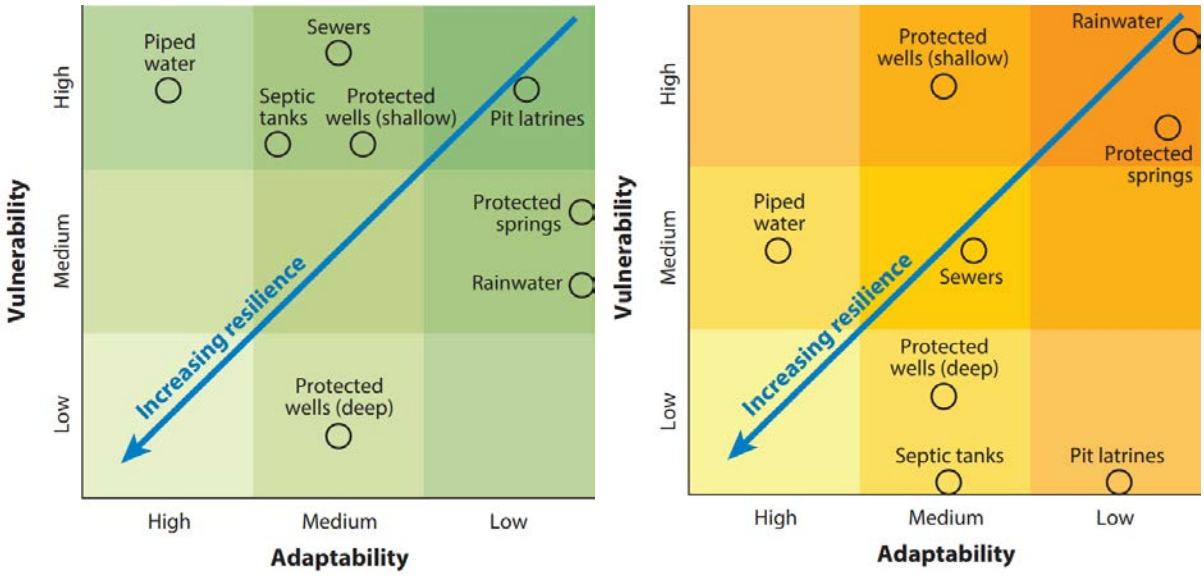
[5] Percentages are added on top of one another as Water.org partners were able to pick multiple climate issues.

	▪ Nevertheless, available top-level data from India, Bangladesh, Cambodia, Indonesia, and The Philippines highlights those improvements financed through WaterCredit programs are generally more resilient to climate change than loan recipients' previous primary water supply sanitation services.		events; however, septic tanks are generally the most resilient and sewers and pit latrines the least. ▪ Sanitation facilities are generally less vulnerable to conditions of decreased rainfall than increased high-intensity rainfall. However, despite being associated with higher service levels, sewers are still deemed moderately vulnerable. ▪ There is a high degree of variance in the resilience of water supply facilities to conditions of both increased high-intensity rainfall or decreased rainfall. However, deep protected well are generally the most resilient technology option, while rainwater harvesting, protected springs and shallow protected wells are the least.

Certain WSS services are generally more resilient than others under given climatic scenarios.

The climate resilience of WSS services varies under different climate forecasts. The climate resilience of a WSS facility is determined by its vulnerabilities to climatic changes and ability to adapt to these changes to reduce vulnerability (University of Surrey, 2010). Selecting appropriate (more climate-resilient) technologies for a given context requires establishing how a technology option performs in the current conditions and against projected future shocks and stresses (Howard, Calow, Macdonald, & Bartram, 2016). Broadly speaking, some WSS services are more climate resilient than others under given climatic scenarios. Figure 7 presents two resilience matrices detailing the vulnerabilities and adaptability of several common improved WSS services to increased intensity of rainfall (in green) and decreased rainfall (in orange).

Figure 7. Water supply and sanitation facility resilience under increased intensity of rainfall (green) and decreased rainfall (orange) (Howard, Calow, Macdonald, & Bartram, 2016)



Most sanitation services have relatively low to moderate resilience to conditions of increased high-intensity rainfall. Sewered sanitation services are highly vulnerable to conditions of high-intensity rainfall. The flooding of sewers and centralized treatment plants can have significant impacts (i.e., raw sewage entering households or the local environment, infrastructure damage), and the size of these facilities means failures often affect large populations (University of Surrey, 2010). Septic tanks and pit latrines are also vulnerable to the various impacts of flooding caused by increased high-intensity rainfall (i.e., sewage discharge into household, structural damage). Nevertheless, a crucial advantage that these facilities have over sewered sanitation is the fact that the impact of a compromised onsite sanitation facility is considerably more contained geographically (University of Surrey, 2010).

Septic tanks and pit latrines continue to perform well under conditions of decreased rainfall, while sewers are moderately vulnerable. Pit latrines have very limited vulnerabilities to conditions of decreased rainfall, and reduced rainfall can reduce vulnerabilities of groundwater contamination (University of Surrey, 2010). Severe water scarcity can impede the ability of septic tanks to function (University of Surrey, 2010). Moderate decreases in rainfall are often beneficial for managing sewer systems; however, it can impede the transport of solids in sewers and the reduced dilution of sewage can impede effective effluent treatment (Aguaconsult, 2021; University of Surrey, 2010).

Despite often providing lower service levels, deep protected wells are the most resilient improved water supply facility to increased high-intensity rainfall – other common improved water supply facilities all have low to medium resilience under this scenario. Piped water supply facilities are highly vulnerable to conditions of high-intensity rainfall and are deemed the improved water supply facility most prone to failure in developing country contexts under this scenario (University of Surrey, 2010). However, they are highly adaptable, meaning they are considered to have a high overall level of resilience when managed by professionalized service providers (University of Surrey, 2010). Protected deep wells have limited vulnerabilities under conditions of increased high-intensity rainfall; however, reduced groundwater quality is a pertinent concern that is especially impactful for shallow protected wells. Protected springs and rainwater collection facilities have moderate vulnerabilities – these primarily relate to water quality and infrastructure damage. These facility types both also have very low levels of adaptability.

There is a comparatively high degree of variance in the resilience of different improved water supply sources under conditions of decreased rainfall. Piped water supply systems are perceived to be moderately vulnerable to conditions of decreased rainfall, with water scarcity being the key vulnerability (especially for systems reliant on surface water) (University of Surrey, 2010). Protected wells face important vulnerabilities to scenarios of decreased rainfall, with falling groundwater levels and the increased salinity of groundwater being the main concerns (University of Surrey, 2010). The depth of the protected well has a significant bearing on the level of vulnerability (see Figure 7). Finally, protected springs and rainwater collection systems have limited resilience to conditions of decreased rainfall because of their reliance on reliable levels of groundwater (protected springs) and rainfall (rainwater collection systems) to ensure water availability.

New types of WSS facilities and adaptions to existing facilities can increase the resilience of WSS services to climate change.

Adaptions and new types of WSS services are required to reduce vulnerabilities to projected climatic changes. As Figure 7 highlights, conventional WSS infrastructure often has limited climate resilience. This does not necessitate abandoning more conventional WSS infrastructure. However, it is necessary to invest in adapting existing WSS infrastructure and constructing more resilient infrastructure. These sorts of investments are usually cost-effective (UN Water, 2019). For example, every dollar spent on strategic flood resilience upgrades could avoid US$62 in flood restoration costs (WaterAid, 2021).

Technology selection and adaptions are especially important for increasing the climate resilience of sanitation services. Understanding local climate risks and selecting appropriate technology options less sensitive to these risks can reduce the vulnerabilities of sanitation services to different climate scenarios (Pacific Institute, 2019). Key modifications to onsite sanitation facilities (i.e., pit latrines) to reduce vulnerabilities to increased high-intensity rainfall include raising the plinth of pits to withstand flood levels, coating pits with cement and mud/sand to prevent erosion during floods and designing smaller or shallower pits. Various often more costly adaptions can also be made to sewage systems and wastewater treatment plants to increase their resilience to conditions of increased high-intensity rainfall. These include installing non-return valves, constructing separate sewage and stormwater sewers, and shifting to renewables and decentralized treatment facilities (Zurbrugg, Koottatep, Sherpa, & Cisse, 2014; Aguaconsult, 2021). Broader efforts to address water scarcity challenges (i.e., promoting reduced water usage, diversification of water supply sources) are vital to mitigating the impacts of water scarcity on sanitation services (Aguaconsult, 2021).

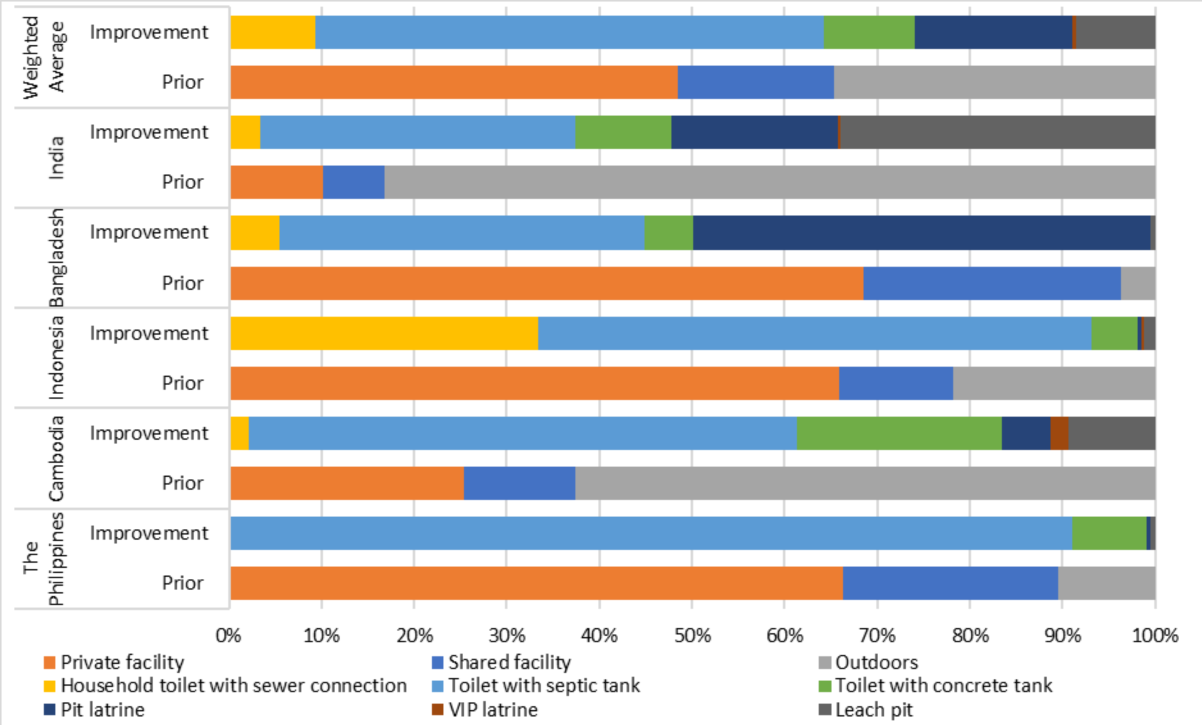
Ensuring the resilience of water supply facilities is a continual process. This makes operations and management and the environment service providers exist within especially crucial in ensuring the climate resilience of water supply facilities (see Sub-Section 3.4.). Under conditions of increased high-intensity rainfall, the main adaptions required relate to ensuring the continued quality of water through protecting water sources from contamination and deteriorating water quality and improving treatment systems (University of Surrey, 2010). For conditions of decreased rainfall, adaptions include seeking alternative water supplies, upgrading treatment systems, and developing greater water storage capacity (University of Surrey, 2010). These adaptions are often comparatively expensive, heightening the importance of more professionalized service providers (see Sub-Section 3.4.).

WaterCredit programs result in households accessing WSS services more resilient to climate change.

Water.org has very limited detailed data on the climate resilience of WSS improvements. Water.org has not systematically collected data on the climate resilience of the WSS improvements financed through WaterCredit programs. This was not an area investigated in the previous program monitoring surveys, and only one evaluation (Bangladesh) focused on this important area. While this evaluation highlighted that many households raised the height of household sanitation facilities to reduce their vulnerability to flooding, the sample size was too small to draw firm conclusions (Water.Org, 2021).

Sanitation improvements financed through WaterCredit programs are generally more resilient to climate change than loan recipients' previous sanitation services. Figure 8 details data from India, Bangladesh, Indonesia, Cambodia, and The Philippines concerning sanitation loan recipients' prior sanitation services and the sanitation improvement financed via WaterCredit. It highlights a considerable shift away from open defecation and the use of shared sanitation facilities, predominantly towards toilets with septic tanks and different variations of pit latrines (i.e., pit latrine, VIP latrine, leach pit). Crucially, septic tanks – and to a lesser extent – pit latrines are largely considered less vulnerable than sanitation facilities connected to sewers under conditions of increased high-intensity rainfall and (especially) reductions in rainfall (Figure 8). Table 6 presents key projected changes in climatology and climate-related natural hazards and provides more information on the broad climate resilience of WaterCredit financed sanitation improvements in India, Bangladesh, Indonesia, Cambodia, and The Philippines.

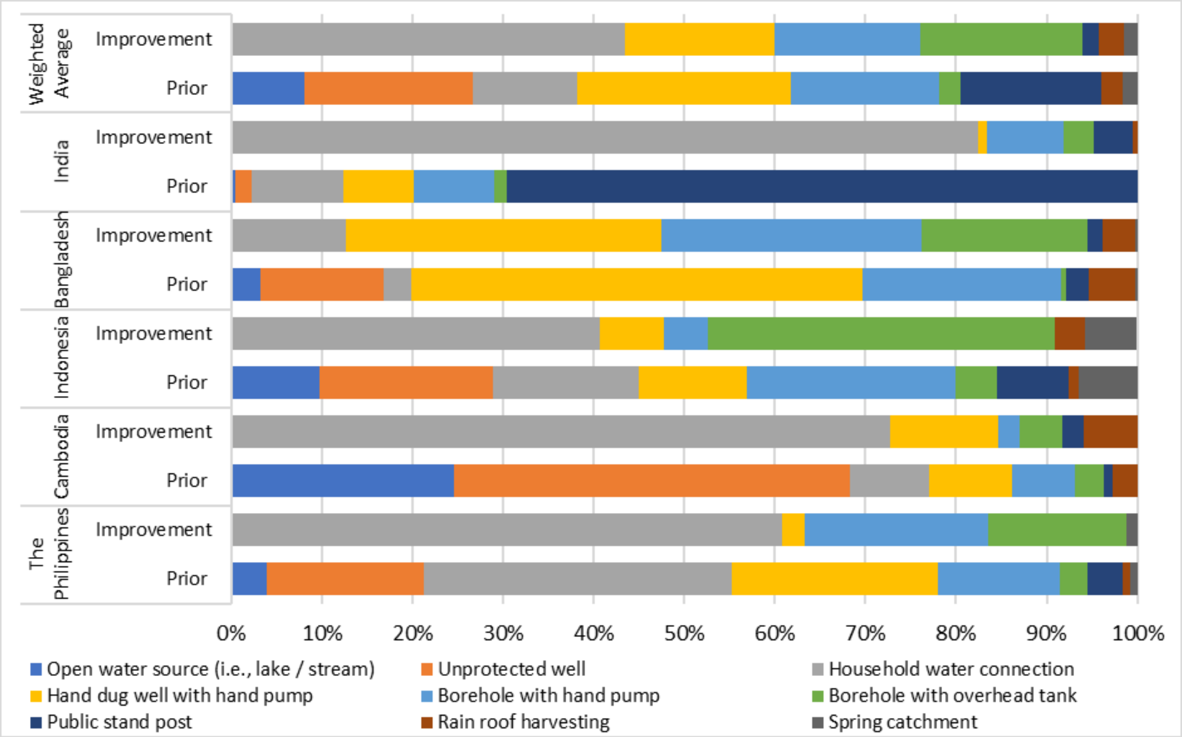
Figure 8. Location of sanitation loan recipients' previous primary sanitation service and the type of sanitation improvement financed through WaterCredit



Water supply improvements financed via WaterCredit programs are generally more resilient to climate change than loan recipients' previous primary water supply source. Figure 8 details water supply loan recipients' primary water source before their new water improvement and what type of water improvement they financed.[6] In very broad terms, this highlights that many WaterCredit water supply loan recipients shifted away from unimproved services such as open water sources and unprotected wells or less sophisticated facilities such as hand-dug well with a hand pump with a very low level of climate-resilience. The most common improvements made were household water connection (43%), followed by boreholes with an overhead tank (18%), hand-dug well with a hand pump (17%), and borehole with a hand pump (16%). Table 6 details key takeaways concerning changes in the resilience of households' primary water source because of WaterCredit programs.

[6] For this analysis, several types of water supply improvements captured in the mWater 2.0 surveys were excluded because of their incomparability to the facilities households used before their water supply improvement. These were: (i) water tank (an improvement financed by 4.19% of households); (ii) water subscription (2.16%); water infrastructure extension (0.45%); water renovation (2.10%); and water filter (water quality) (4.17%). Additionally, the categories borehole with overhead tank and borehole recharge structure were combined for the purpose of the analysis for the question 'What type of water improvement(s) is it?'.

Figure 9. Water supply loan recipients' previous primary water source and the type of water improvement financed through WaterCredit



Most Water.org MFI partners have made some changes to their WSS loans or products to better respond to the impacts of climate change. Figure 10 is based on the Climate Change Partner Survey and details what WSS loan products / services Water.org MFI partners offer due to climate change.[7] It shows that 61% of Water.org MFI partners are making some adaptions to their loans or products to better respond to the impacts of climate change. The most common adaption was providing loan options for more climate-resilient infrastructure (48%). This was followed by adjusting loan terms (24%), adjusting client eligibility criteria (23%), and providing larger loan amounts for more expensive WSS improvements (7%).

[7] Percentages are added on top of one another as Water.org MFI partners were able to pick multiple climate issues.

Figure 10. What water and sanitation loan products / services does your microfinance institution offer due to climate change? (Climate change partner survey, Water.org)

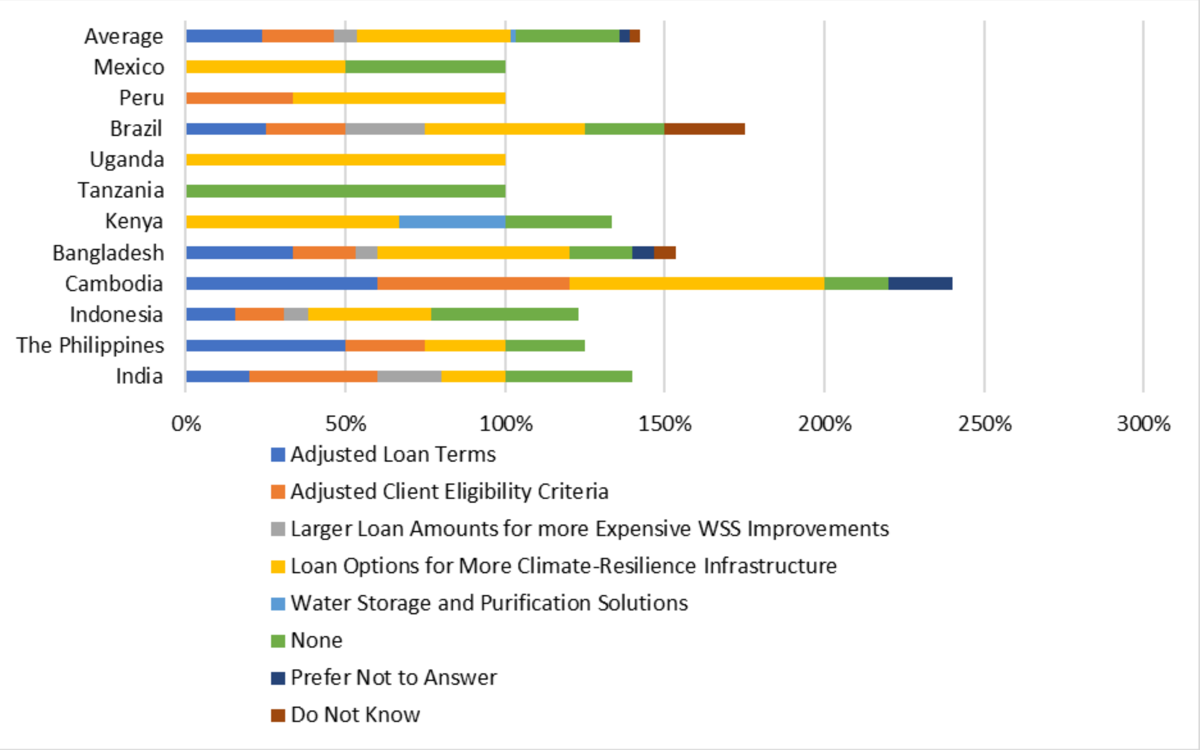


Table 6. Resilience of WaterCredit financed WSS improvements to projected climatic changes

Country	Climate Future	Climate-Related Natural Hazards	Climate Resilience of WaterCredit Financed Water Supply Improvements	Climate Resilience of WaterCredit Financed Sanitation Improvements
India	0.9-17°C temperature rise by 2050; considerable uncertainty regarding precipitation	Very high exposure to flooding (riverine, flash, and coastal) and high exposure to tropical cyclones (and their associated hazards) and extended drought.	▪ Most improvements are household connections to piped water supply services (73%). Despite generally providing higher services levels, this technology is often more vulnerable to high-intensity rainfall events – and to a lesser extent – low rainfall conditions than many other improved water supply services (i.e., deep protected wells).	▪ Considerable shift away from open defecation (83%) reduces vulnerabilities to flooding and tropical cyclones because of the reduction in human excreta entering the environment during these events. ▪ Most improvements are different variations of pit latrines (52%), which have limited resilience to conditions of increased high-intensity rainfall but very low vulnerability to conditions of decreased rainfall. ▪ Many improvements are septic tanks (34%) that are more resilient than sewers, pit latrines, and open defecation to high-intensity rainfall or decreased rainfall. ▪ A very small percentage of improvements are household toilets with sewer connections (3%). Despite typically providing higher service levels, this technology option is highly vulnerable to conditions of increased high-intensity rainfall.
Bangladesh	1.5°C temperature rise by 2050; increased precipitation (20-30% by 2050), water availability and peak 5-day rainfall intensity.	Increased high-intensity rainfall events, with increased frequency of tropical cyclones and cyclone-induced storm surges and flooding.	▪ Shift away from open water sources (3%) and unprotected wells (14%) reduces vulnerabilities to expected increased overall rainfall and high-intensity rainfall events. ▪ Many improvements are household connections to piped water supply systems (13%) or hand-dug wells with hand pumps (35%) that are highly vulnerable to projections of increased rainfall intensity. ▪ Financed boreholes with hand pumps (29%) and boreholes with overhead tanks (19%) (especially deep boreholes) should be more resilient to expected climatic changes.	▪ Small shift away from open defecation (4%) reduces vulnerabilities to flooding and tropical cyclones because of the reduction in human excreta entering the environment during these events. ▪ Most improvements are pit latrines (49%), which are highly vulnerable and have very limited adaptability (low overall resilience) to conditions of increased high-intensity rainfall. ▪ Many improvements are septic tanks (39%) that are generally more resilient than sewers, pit latrines, and open defecation to conditions of increased high-intensity rainfall. ▪ Only a small percentage of improvements are household toilets with sewer connections (5%). Despite typically providing higher service level, this technology option is highly vulnerable to conditions of increased high-intensity rainfall.
Indonesia	0.8-1.5°C temperature rise by 2040-2059; minor increase in annual precipitation	Faces high disaster risk levels, especially for all types of flooding (riverine, flash, and coastal) and to a slightly lesser extent tropical cyclones.	▪ Shift away from open water sources (10%) and unprotected wells (19%) reduces vulnerabilities to flooding and high-intensity rainfall events. ▪ Shift to boreholes with overhead tanks (38%) increases resilience to flooding and high-intensity rainfall events, especially where these are deep boreholes.	▪ Shift away from open defecation (22%) reduces vulnerabilities to flooding and tropical cyclones because of the reduction in human excreta entering the environment during these events. ▪ Most improvements are septic tanks (60%), which are generally more resilient than sewers, pit latrines, and open defecation to conditions of increased high-intensity rainfall. ▪ Many improvements are household toilets with a sewer connection (33%). Despite typically providing higher service levels, this

Country	Climate Future	Climate-Related Natural Hazards	Climate Resilience of WaterCredit Financed Water Supply Improvements	Climate Resilience of WaterCredit Financed Sanitation Improvements
			▪ Many improvements are household connections to piped water supply services (41%). Despite generally providing higher services levels, this technology is often more vulnerable to flooding and high-intensity rainfall events than many other improved water supply services.	technology option is generally more vulnerable than septic tanks and pit latrines to conditions of increased high-intensity rainfall. ▪ Only a very small percentage (<2%) of improvements are variations of pit latrines (pit latrine, VIP pit latrine, leach pit) that are generally highly vulnerable and have low adaptability to conditions of increased high-intensity rainfall.
Cambodia	0.9-1.7°C temperature rise by 2040-2059; minor increase in annual precipitation.	Faces high disaster risk levels, especially riverine and flash flooding. More severe droughts and flooding are projected.	▪ Substantial shift away from open water sources (25%) and unprotected wells (44%) reduces vulnerabilities to flooding caused by high-intensity rainfall events and conditions of low rainfall. ▪ Most improvements are household connections to piped water supply services (73%). Despite generally providing higher services levels, this technology is often more vulnerable to high-intensity rainfall events – and to a lesser extent – low rainfall conditions than many other improved water supply services.	▪ Considerable shift away from open defecation (63%) reduces vulnerabilities to different types of flooding because of the reduction in human excreta entering the environment during these events. ▪ Most sanitation improvements are septic tanks (59%), which are generally more resilient than sewers and pit latrines to both conditions of increased high-intensity rainfall and decreased rainfall. ▪ Only a small percentage of improvements are household toilets with sewer connections (2%). Despite typically providing higher service levels, this technology option is highly vulnerable to conditions of increased high-intensity rainfall and more vulnerable than septic tanks and pit latrines to conditions of decreased rainfall.
The Philippines	0.9-1.5°C temperature rise by 2040-2059; moderate increase in annual precipitation and intensity of sub-daily extreme rainfall events.	Faces some of the highest disaster risks levels globally. Is especially exposed to tropical cyclones, flooding and landslides and these are projected to intensify.	▪ Shift away from open water sources and unprotected wells reduce vulnerabilities to flooding and high-intensity rainfall events. ▪ Many improvements are household connections to piped water supply services (61%). Despite generally providing higher services levels, this technology is often more vulnerable to flooding and high-intensity rainfall events than many other improved water supply services. ▪ Many households' shift to boreholes with hand pumps (20%) or overhead tanks (15%) should result in services with a higher-level of climate resilience to high-intensity rainfall events, especially where these are deep boreholes.	▪ Small shift away from open defecation (10%) reduces vulnerabilities to different types of flooding and tropical cyclones because of the reduction in human excreta entering the environment during these events. ▪ Substantial percentage of sanitation improvements are septic tanks (91%), which are generally more resilient than sewers, pit latrines, and open defecation to conditions of increased high-intensity rainfall. ▪ No improvements are household toilets with sewer connections. Despite typically providing higher service levels, this technology option is highly vulnerable to conditions of increased high-intensity rainfall.

3.3 Multiple water supply and sanitation services

Table 7. RAG rating for evidence of multiple water supply and sanitation services

Internal data	▪ Water.org has not systematically collected data on WaterCredit programs' impact on households use of multiple WSS services, let alone the effect of this on households' climate resilience. ▪ The only statistically significant information available comes from an endline evaluation of WaterCredit in Cambodia. This indicates a limited impact on the number of water points used by households and does not provide data on households' ability to access multiple water points.	**External data**	▪ Households often purposively adopt a portfolio of different water supply sources. ▪ The ability to access WSS services differentially vulnerable to varying shocks and stresses decreases the possibility that all available WSS services become unusable during a single event. ▪ Climate change increases the importance of being able to access multiple WSS services as different WSS services often have differential levels of resilience under different climate change scenarios.

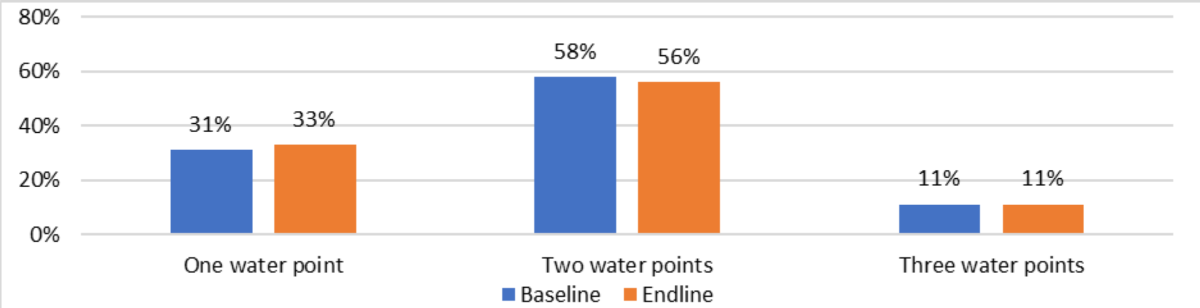
Multiple-use WSS services are an important – and often neglected – component of climate-resilient WSS service provision.

Considerations of climate-resilient WSS often neglect multiple household water sources. The use of multiple household water sources is practiced in wide-ranging contexts. For example, the use of different water supply sources in the rainy and dry seasons or the use of different water supply sources for different uses (i.e., drinking, domestic). Understanding households' use of multiple water supply sources to meet their various needs is, therefore, important to understanding their climate resilience and designing appropriate adaption options (Elliott, et al., 2017). However, research on climate-resilient water supply services often focuses on the resilience of households' primary water supply source, neglecting how the use of alternative or multiple water supply sources can increase resilience.

Accessing multiple water supply sources enhances households' climate resilience. The ability to access water from sources differentially vulnerable to varying shocks and stresses decreases the probability that all available water supply sources become unusable during a single event (Elliott, et al., 2019). Indeed, households often purposively adopt a portfolio of different water sources to reduce overreliance and depletion of a single highly valued source, thereby bolstering resilience (Elliott, et al., 2019). Diversifying risk in this way is increasingly important because different water supply services often have varying levels of vulnerability to different weather-related shocks and stresses or broad climate change scenarios (see Figure 7). For example, being able to access a nearby deep protected well can mitigate the high vulnerability and low adaptability of rainwater harvesting systems under conditions of decreased rainfall. Less research has been conducted on the benefits of households being able to access multiple sanitation facilities; however, there are instances where this increases climate resilience. For example, sewers, septic tanks, and pit latrines each have varying levels of vulnerability to conditions of increased high-intensity rainfall intensity and especially decreased rainfall (see Figure 7).

Water.org has limited data on the impact of WaterCredit programs on households' ability to access multiple WSS services. Water.org has not systematically collected data on WSS loan recipients' ability to access multiple WSS services, let alone the impact of this of households' climate resilience. The only statistically significant information available on this area comes from an endline evaluation of WaterCredit in Cambodia. This indicated that the WaterCredit program had a limited impact on the number of water points used by households and does not provide data on households' ability to access alternative WSS services. Of note, most households at both baseline and endline reported using a secondary source for water collection in addition to their primary water source (see Figure 11).

Figure 11. Use of multiple water points – WaterCredit Cambodia program (Causal Design, 2020)



3.4 Strengthened water supply and sanitation actors

Table 8. RAG rating for evidence of strengthened water supply and sanitation actors

Internal data	▪ Water.org has not previously collected any data on the extent to which WaterCredit programs increase partner MFIs or WSS loan recipients' knowledge of the impacts of climate change and whether they are using this information to tailor WSS improvements to address or mitigate these. ▪ 61% of Water.org partners report that incorporating lending for WSS into their loan portfolios increases their knowledge of how climate-related events can affect WSS services. ▪ WaterCredit programs do not currently sufficiently attempt to bring about knowledge transfer to loan recipient households on key aspects related to their WSS improvement and climate change.	**External data**	▪ Actors at a variety of levels are crucial to ensuring the climate resilience of WSS services. ▪ Households and communities are crucial actors in ensuring WSS services are climate-resilient, and knowledge transfer to households and communities is key to increasing the climate resilience of WSS services. This is especially true for demand-driven implementation modalities such as those employed by Water.org. ▪ Service providers play a crucial role in bolstering the climate resilience of WSS services, especially for water supply services. ▪ Strong actors at the sub-national and national levels that effectively perform their roles and responsibilities are crucial in increasing the climate resilience of WSS service provision.

Households can play a critical role in ensuring the climate resilience of their WSS services.

Ex **Households and communities are crucial actors in ensuring WSS services are climate-resilient.** Local communities know and experience local climate conditions. While climate change often accentuates extreme weather events, this knowledge can be critical in reducing risks to WSS services. Indeed, traditional knowledge among local communities and households can help to provide efficient, appropriate, and time-tested ways of adapting to climate change and complementing other adaption measures (UNFCCC, 2007). For example, interesting examples of community and household adaptions to the flooding of sanitation facilities have bolstered the climate resilience of these facilities (Jabeen, Allen, & Johnson, 2010; Adelekan, 2010).

Ex **Knowledge transfer to households and communities can play a central role in increasing the climate resilience of WSS services.** Knowledge transfer is necessary to support communities and households to further bolster their climate resilience, and match or complement traditional knowledge with interventions to increase climate resilience. Knowledge transfer to communities and households is one of the key adaptions relevant to all climate scenarios and types of WSS services (University of Surrey, 2010). Common forms of knowledge transfer include, for example, detailing local climatic threats to WSS services and highlighting more resilient services, infrastructural options, and management practices. Knowledge transfer is especially important within the context of the demand-driven approach adopted by WaterCredit programs. This is because households select the WSS improvement(s) that WaterCredit programs finance, giving them considerable say over the selection of more (or less) climate-resilient technologies. Moreover, many WSS loan recipients select technologies (i.e., septic tanks, pit latrines, rainwater harvesting systems) they are responsible for managing, heightening the importance that they understand local climatic threats and appropriate adaption strategies.

Water.org currently has very limited data on knowledge transfer to communities and households on key aspects of the interlinkage between climate change and WSS service provision. No WaterCredit programs have had the explicit objective of increasing households' knowledge of climate change and its impact on WSS services. Consequently, Water.org has not systematically collected data on key areas in this regard. For example, this is not an area addressed in the program monitoring surveys (see Section Five), and it has also not been a focus area for any of WaterCredit program evaluations.

WaterCredit programs increase partners' knowledge in key areas but are not currently leading to sufficient levels of knowledge transfer on climate change to loan recipients. Figure 12 details information from the partner climate change survey on whether incorporating lending for WSS into Water.org partners' loan portfolios has increased their knowledge of how climate-related events can affect WSS services. It highlights that most (61%) Water.org partners reported that their knowledge in this area increased, with 18% reporting that there had not been an increase. As the actors that would organize training for households and sensitize them on issues related to climate change and their WSS improvement, this is crucial to effective knowledge transfer.

Figure 12. Has incorporating lending for water supply and sanitation into your portfolio increased your knowledge of how climate-related events can affect water supply and sanitation services? (Climate change partner survey, Water.org)

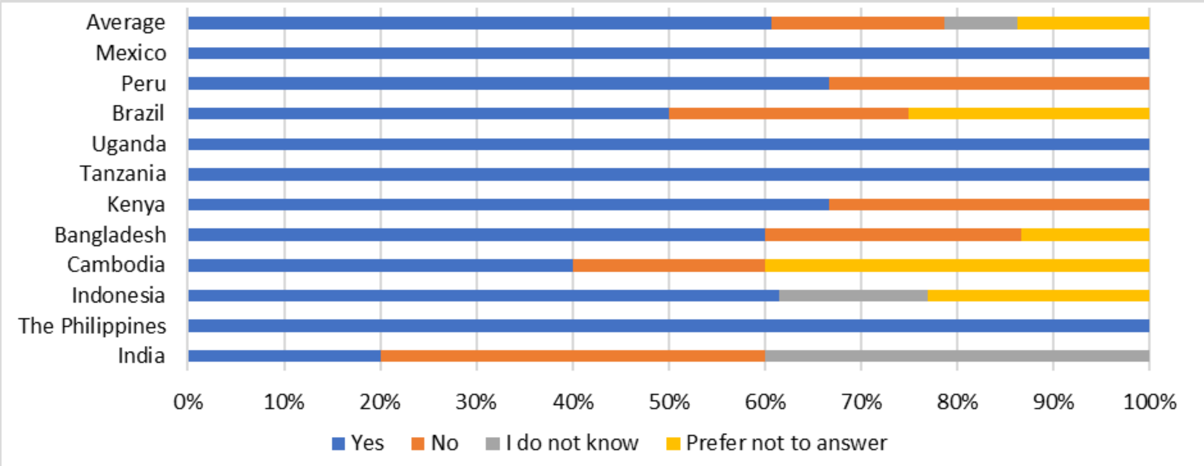
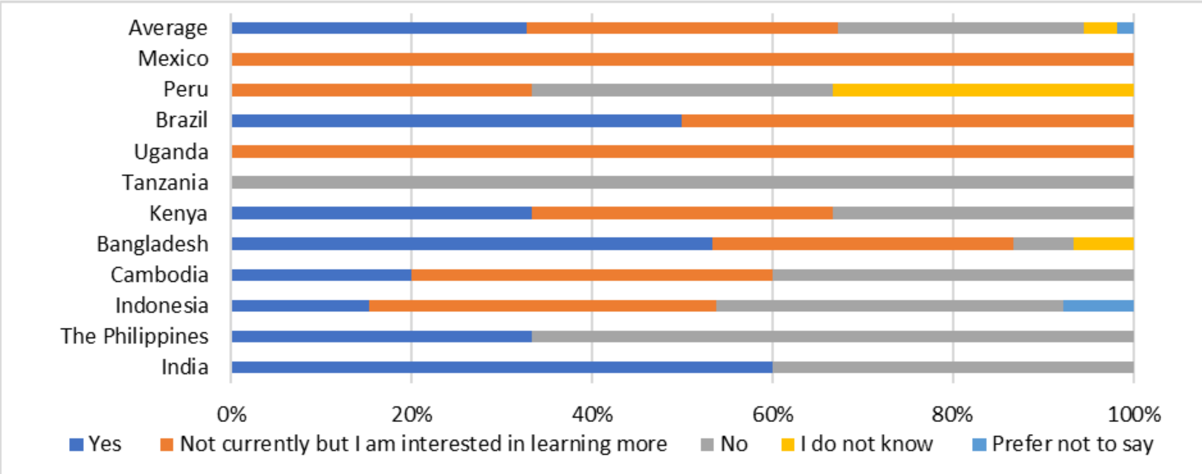


Figure 13 shows information from the partner climate change survey on whether Water.org partners communicate with loan recipient households on which WSS improvements are more resilient to climate-related shocks and stresses. It highlights that only 32% of Water.org partners currently include aspects related to climate change in the training provided to loan recipient households. 26% of respondents stated that training does not focus on these aspects, while 33% stated that while trainings do not focus on these aspects at the moment, they would be interested in learning more about how they could do this. Overall, this data indicates that WaterCredit programs do not currently sufficiently attempt to bring about knowledge transfer to loan recipient households on the impacts of climate change on WSS services, which WSS services are more climate resilient to the specific threats faced in their locality, and measures that can be taken to increase the climate resilience of a given WSS improvement.

Figure 13. Do you provide training to households that includes guidance on which water supply and sanitation services are more resilient to climate-related shocks and stresses? (Climate change partner survey, Water.org)



Service providers play a crucial role in bolstering the climate resilience of WSS services, especially for water supply services.

Ex **Effective operations and management of WSS services are required to ensure the climate resilience of these services.** To varying extents, the proper management of WSS services is required to maximize their resilience to different climate change scenarios – the selection of appropriate technologies for local climatic conditions is rarely sufficient. All WSS services must be managed throughout their lifespan to ensure they continue delivering services; however, widespread challenges exist in managing WSS services in low- and middle-income countries, especially in rural contexts.[8] Climate change exacerbates existing challenges in managing WSS services, while also creating a range of new obstacles for service providers to overcome. These challenges necessitate further attention being given to this often-neglected aspect of WSS service delivery.

Ex **Service providers are especially important in increasing the climate resilience of water supply services.** The proper operations and management of water supply facilities are the most important factor in increasing the climate resilience of these services (Oates, Ross, Calow, Carter, & Doczi, 2014; Howard, et al., 2010). This is in a large part because many of the adaptions required to ensure the continued operations of these services (i.e., new water source development, replacement of damaged infrastructure, increased water treatment, proper asset management) require substantial human and financial resources and must be undertaken on an ongoing and recurrent basis. These resource requirements are often far beyond what are available to small, deconcentrated service providers such as water committees. Accordingly, various studies have considered the type of service provider as a crucial factor in broadly quantifying the climate resilience of different water supply services. For example, as a technology, piped water supplies have a low adaptive capacity (University of Surrey, 2010). This causes them to be deemed vulnerable to several broad climate change scenarios and have

[8] This is illustrated by alarming statistics such as high non-functionality and non-revenue water rates as well as the considerable percentages of human excreta entering the environment.

a low overall level of climate resilience when managed by water committees (University of Surrey, 2010). However, due to the personnel and financial resources available to many utility-managed piped water supplies, their adaptive capacity is considered high, and their overall climate resilience is much higher than for community-managed piped water supply facilities (University of Surrey, 2010).

In

The impact of WaterCredit programs on supporting the more professionalized operations and management of WSS services is unclear. A few Water.org evaluations have highlighted instances where WaterCredit programs have supported the operations and management of WSS services by more professionalized service providers such as national or regional utilities and private operators. For example, in Indonesia, Water.org worked with partner MFIs to develop loan products for small enterprises involved in managing peri-urban and rural water systems. However, this is not an area Water.org periodically captures data on. Information is not collected, for example, on the types of service providers managing the WSS improvements financed through WaterCredit programs. This means that this meta-study cannot determine whether – and the extent to which – WaterCredit programs are supporting the increased climate resilience of WSS services through the more professionalized management of services.

Strong actors at the sub-national and national levels that effectively perform their roles and responsibilities are crucial in increasing the climate resilience of WSS service provision.

Ex

Actors at the sub-national and national levels have a crucial role in ensuring climate resilient WSS service provision. Governmental actors at the sub-national and national levels are central WSS service provision, holding critical legislative, policy, and planning functions as well as regulatory responsibilities to ensure the proper management of WSS services. The requirement for largescale improvements in WSS service provision brought about climate change further heightens the importance of these responsibilities. The measures required by national and sub-national governmental actors are diverse and cannot be properly detailed here. However, key actions include measures such as adapting guidance on infrastructure construction in different contexts to reflect different climatic threats and WSS improvements' varying levels of resilience. Other crucial measures include increasing support and guidance to service providers and ensuring regulatory and monitoring mechanisms account for crucial elements of climate resilience.

In

There is no available data on WaterCredit programs' impact on sub-national and national actors' performance of their responsibilities related to increasing the climate resilience of WSS service provision. Several recent studies have investigated Water.org's impact on systems change, including impacts at the national and sub-national levels. None of these, however, focused explicitly on issues related to climate change. Moreover, the impact of Water.org programs at the national and sub-national levels are rarely focused on in the evaluations conducted for WaterCredit programs. Consequently, there is currently no internal Water.org evidence-base on the impact of WaterCredit programs on sub-national and national actors' performance of their responsibilities related to increasing the climate resilience of WSS service provision. This meta-study cannot, therefore, make any conclusions in this area.

3.5 Greenhouse gas emissions and environmental impact

Table 9. RAG rating for evidence of energy-use and GHG emissions

Internal data	▪ Water.org has not collected any data on the energy use and associated GHG emissions of WaterCredit financed WSS services. ▪ Water.org has not collected sufficiently detailed information on key contextual data	**External data**	▪ WSS services are responsible for a considerable proportion of global energy production and GHG emissions.

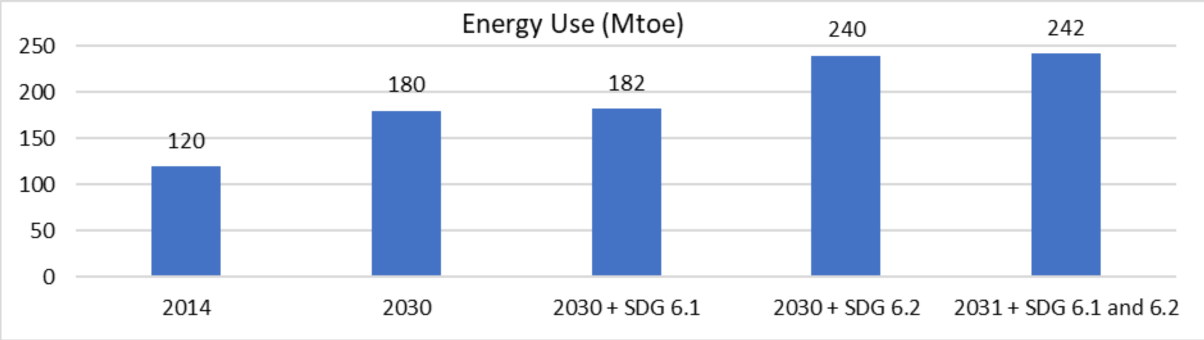
	points (i.e., water source, groundwater source depth, pump efficiency) required to estimate the energy-use of WaterCredit financed water supply improvements. ▪ 55% of WaterCredit loan recipients constructed a toilet with septic tank. Septic tanks are typically associated with lower GHG emissions than sewered sanitation and treatment at a centralized treatment facility (representing 9% of WaterCredit financed sanitation improvements); however, it is usually associated with greater GHG emissions than pit latrines (26%). ▪ Water.org has not collected data on interventions to reduce the GHG emissions of WaterCredit financed WSS services. ▪ 71% of Water.org supported WSS service providers are interested in reducing their carbon footprint. ▪ Water.org has comparatively limited data on environmental impacts from WaterCredit financed WSS improvements. Nevertheless, many WaterCredit programs lead to a shift away from open defecations, reducing harm to ecosystems through pathogens and nutrient overload (especially where these lead to in-situ disposal and treatment of human excreta).		▪ The energy requirements and GHG emissions of different water supply facilities vary considerably. ▪ Improved WSS services will ultimately be critical to climate change mitigation and adaption. ▪ Various factors influence the energy use and GHG emissions of WSS services. For water supply services, these include the water source, reliance on energy for transporting water, depth of groundwater sources, and the efficiency of pumps and treatment systems. ▪ Three main strategies exist for reducing the GHG emissions from WSS services: (i) water-use efficiency; (ii) energy efficiency; and (iii) renewable energy. ▪ Water supply and sanitation improvements can also have a variety of positive and negative impacts on their local ecosystems. These span direct impacts such as over-abstraction and contamination through open defecation and the disposal of untreated wastewater as well as indirect impacts such as well as indirect impacts such as reduced deforestation.

Improved WSS services will ultimately be critical to climate change mitigation and adaption. While the energy needs of WSS services result in significant GHG emissions, GHG emissions reduction activities are often dependent on a stable supply of adequate quality water (UN Water, 2019). It is also important to consider the negative impacts of WSS services on GHG emissions within the context of the much lower overall GHG emissions by low- and lower-middle-income countries and the key benefits resulting from accessing WSS services (see other thematic papers). Accordingly, efforts to limit GHG emissions globally cannot come at the cost of preventing or limiting progress ensuring universal access to safe and reliable WSS services. However, it is increasingly necessary to limit the impacts of existing and new WSS services concerning GHG emissions.

Water supply and sanitation services are responsible for a considerable proportion of global energy production and GHG emissions.

WSS services account for about 1.2% of total global energy production. As Figure 14 highlights, energy use for WSS services was estimated to result in 120 million tons of oil equivalent (Mtoe) in 2014, equating to 1.2% of total global energy production (Pacific Institute, 2019). Even without equating for the additional WSS services required to meet SDG Six, energy use by WSS services is projected to rise by 50% from 2014 levels to 180 million Mtoe in 2030. As Figure 14 details, a further small increase in energy use would occur if SDG 6.1 on universal drinking water is met as well as a much larger increase if SDG 6.2 on universal sanitation was met.

Figure 14. Energy use for WSS services in 2014 and 2030, with and without meeting SDGs 6.1 and 6.2 (Pacific Institute, 2019)



Ex

Sanitation services also contribute to GHG emissions through the degradation of organic matter. In addition to the large energy-use requirements of many sanitation services (primarily through the energy used by centralized treatment plants), degradation of organic matter during wastewater treatment contributes roughly 1.5% of global GHG emissions and 5% of global non-carbon dioxide GHG emissions (Dickin, Bayoumi, Gine, Andersson, & Jimenez, 2020). The discharge of untreated waste into the environment and the use of on-site technologies (i.e., septic systems, pit latrines) are also less substantial – but still significant – sources of emissions (Reid, Guan, Wagner, & Mauzerall, 2014). There is substantial potential to reduce the GHG emissions of urban sanitation facilities. For example, "energy recovery for all new centralized wastewater treatment capacity in urban areas could generate 50 percent more energy than needed for safely managed sanitation" (Pacific Institute, 2019).

Ex In

The energy requirements and GHG emissions of different water supply facilities vary considerably. The largest source of GHG emissions from WSS services is their energy use (i.e., electricity, natural gas, diesel, and biogas produced on-site). The levels of energy use by different water supply facilities are largely driven by the fuels used to generate electricity and the levels of electricity required to move the water from its source (i.e., groundwater) to the point of consumption. Local estimates are required to reliably quantify potential energy and GHG emissions associated with given WSS services (Pacific Institute, 2019). Nevertheless, Table 10 details the energy requirements of several common water supply improvements predominantly used to serve rural households and communities in bringing water to the point of distribution. It highlights the variation in the energy requirements of different water supply facilities as well as the central importance of the depth and efficiency of mechanized pumps in influencing the energy requirements of water supply facilities supplied via groundwater sources. Because of the significance of factors such as these that Water.org does not have internal data on, it is not possible to draw meaningful insights on the levels of energy-use of water supply improvements financed via WaterCredit.

Table 10. Energy requirements (KWh/m3) for several common water supply improvements in bringing water to the point of distribution (Pacific Institute, 2019)

Water Supply Improvement	Energy Use (KWh/m3)
Protected Spring	0
Groundwater – hand pump or bucket and pulley	0
Groundwater – mechanized pump (shallow, high efficiency)	0.170
Groundwater – mechanized pump (shallow, low efficiency)	0.454
Groundwater – mechanized pump (medium depth, high efficiency)	0.340
Groundwater – mechanized pump (medium depth, low efficiency)	0.908

Groundwater – mechanized pump (deep, high efficiency)	1.021
Groundwater – mechanized pump (deep, low efficiency)	2.724
Rainwater harvesting system	0.2-1.4

The GHG emissions resulting from sanitation services vary significantly. Table 11 details the emissions (methane and nitrous oxide) levels of different forms of wastewater discharge and treatment. It highlights important variations in the emissions levels between different forms of wastewater discharge and treatment.

Table 11. Methane and nitrous oxide emissions for wastewater discharge and treatment systems (Pacific Institute, 2019)

Wastewater Discharge / Treatment Description	Emissions Factor	
	Kg CH_4 (Methane) / kg BOD	Kg N_2O-N (Nitrous Oxide)/Kg N (Nitrogen)
Wastewater Discharge (Treated or Untreated)		
Open Defecation	0	0
Discharge to Water Bodies	0.114	0.005-0.019
Flowing Sewer (Open or Closed)	0	0
Stagnant Sewer (Open and Warm)	0.3	0
Wastewater Treatment		
Latrine (dry climate, ground water table lower than latrine, small family of 3-5 persons)	0.06	0
Septic tank	0.3	0
Aerobic treatment plant	0.018	0.016
Anaerobic reactor	0.48	0

A mixed picture exists regarding the GHG emissions from sanitation facilities constructed through WaterCredit programs. Water.org's internal data does not enable a precise estimation of the energy-use and GHG emissions from sanitation facilities financed via WaterCredit programs. For example, data is not, for understandable reasons, collected on important contextual factors such as the height of the groundwater table in relation to the pit latrine or the form wastewater treatment. Nevertheless, a few broad findings are observable based on data on the sanitation facilities constructed by WaterCredit loan recipients from Bangladesh, Cambodia, India, Indonesia, and The Philippines (see Figure 8):

1. 55% of WaterCredit loan recipients constructed a toilet with septic tank. This is associated with lower GHG emissions than sewered sanitation and treatment at a centralized treatment facility; however, it is usually associated with greater GHG emissions than pit latrines.
2. 26% of Water Credit loan recipients constructed a form of pit latrine (i.e., pit latrine, VIP pit latrine, leach pit). While there is a high degree of variation in GHG emissions levels from these facilities, forms of pit latrines are associated with comparatively low levels of GHG emissions.
3. Only 9% of WaterCredit loan recipients constructed a toilet connected to a sewer. Despite typically providing higher service levels, this technology option is deemed to be highly vulnerable to conditions of increased high-intensity rainfall.

Many interventions can reduce the GHG emissions from WSS services.

Three main strategies exist for reducing the GHG emissions from WSS services. Interventions to reduce WSS services' GHG emissions can be grouped into three core sets of activities (Pacific Institute, 2019):

1. *Water-Use Efficiency*. Saving water saves energy, making efforts to increase water-use efficiency crucial to reducing the energy requirements – and associated GHG emissions – of WSS services. In developing country contexts such as those Water.org operates in, water loss

rates frequently exceed 35%, and efforts to reduce the physical water losses that represent about 60% of this amount can yield significant water – and, in turn, energy – savings.

2. *Energy Efficiency*. Improved energy efficiency reduces the energy use of WSS services. Possible improvements for water supply facilities include relying on gravity whenever possible to move water as well as optimizing pumping systems (i.e., correctly sized pumps, variable speed drivers, timely replacement of inefficient pumps). For example, a 500-person community pumping enough groundwater to meet basic water needs (50 LPCPD) from 100 meters depth would reduce their energy use by about 5,200 kWh per year by replacing inefficient pumps.
3. *Renewable Energy*. Switching from fossil fuel to renewable-based WSS services ensures significant GHG emission reductions. Many WSS services' energy requirements can be met through renewables such as solar, wind, biomass, and biofuels. Additionally, domestic wastewater can provide a renewable energy source capable of fair exceeding requirements for wastewater treatment.

Water.org has not systematically collected any data on interventions made to reduce the GHG emissions of WSS services financed through WaterCredit programs. Of the seven Water.org supported WSS service providers surveyed for the Partner Climate Change Survey, five (71%) stated that they were interested in reducing their carbon footprint in how they source, treat, and distribute water or treat wastewater. These five actors saw the following opportunities for action in this area:

1. 100% – switch to renewable energy sources.
2. 100% – increase operational efficiencies.
3. 100% – minimize the pumping and treatment of surface water.
4. 100% – tap into government programs and / or investment opportunities.
5. 80% – switch conventional processes to lower-energy alternatives.
6. 20% – onsite energy generation.

All five of these actors have climate change plans or strategies in place or under development but asserted the need for a variety of additional types of support from Water.org.

Water supply and sanitation improvements can also have a variety of positive and negative impacts on their local ecosystems.

Water supply and sanitation services can directly and indirectly affect the resilience of ecosystems and their ability to withstand climatic changes. Ecosystems are fragile and interconnected webs of species and habitats. Small changes to these local ecosystems can have wide-ranging repercussions for a whole suite of species. In turn, this can drastically impact the resilience of ecosystems and their ability to withstand future shocks and stresses such as those brought about by climatic changes (Bonnardeaux, 2012). WSS services can positively and negatively impact their local ecosystems in a variety of ways. This includes direct impacts such as through the over-abstraction of available water sources as well as contamination through open defecation and the disposal of untreated wastewater. It can also include indirect impacts such as reducing deforestation by limiting requirements for boiling water and aiding the development of a sense of stewardship to protect ecosystems and natural resources (Africa Biodiversity Collaborative Group, 2013).

Open defecation and the disposal of untreated or improperly treated wastewater contaminate land and aquatic ecosystems. Without proper treatment, fecal sludge and wastewater can harm ecosystems through pathogens and nutrient overload (WaterAid, 2021). Sanitation improvements can, therefore, "directly benefit ecosystems by reducing fecal contamination on land and in water, reducing nutrient loadings to streams and lakes, making aquatic and terrestrial ecosystems healthier" (Africa Biodiversity Collaborative Group, 2013).

WaterCredit programs positively impact sensitive local ecosystems by limiting open defecation; however, the extent of positive impacts from WaterCredit programs is unclear. Water.org does not have internal data on the percentage of sanitation facilities constructed through WaterCredit programs that ultimately result in the safe management of human excreta. This covers a lack of data for sewered sanitation services as well as non-sewered services where human excreta are supposed to be treated and disposed of in-situ or stored temporarily and then emptied and treated off-site. Nevertheless, Figure 8 presents data from India, Bangladesh, Indonesia, Cambodia, and The Philippines concerning sanitation loan recipients' prior sanitation services and the sanitation improvement financed via WaterCredit. It highlights a considerable shift away from open defecation and shared sanitation facilities, predominantly towards toilets with septic tanks and different variations of pit latrines (i.e., pit latrine, VIP latrine, leach pit). Shit Flow Diagrams from many of the contexts where Water.org operates highlights that a considerable percentage of human excreta from different sewered and non-sewered sanitation facilities are ultimately not safely treated (Alliance, 2021). Nevertheless, the shift away from open defecation reduces the harm to ecosystems through pathogens and nutrient overload, especially where these lead to in-situ disposal and treatment of human excreta.

Water supply improvements can reduce pressure on freshwater ecosystems and limit the over-abstraction of surface water sources; however, the extent of the impact of WaterCredit programs in this area is unclear. Demographic changes such as population growth and rapid urbanization place increasing pressure on surface water sources (i.e., reservoirs, lakes, rivers). This makes well-designed and managed water supply facilities increasingly important for ensuring the more efficient use of resources that reduce unsustainable water abstractions (WaterAid, 2021). Water.org has extensive data on loan recipients' primary water source before and after their water supply improvement (see Figure 8). This highlights that many loan recipients shifted away from utilizing surface water sources to facilities supplied by groundwater sources (i.e., boreholes with an overhead tank or hand pump). Groundwater sources are typically more resilient to climate change than surface water and are generally an effective means to satisfy the ever-increasing water demands and deal with surface water shortages (Zhang, 2015). However, data is not available on key aspects required to determine the impact of WaterCredit financed improvements on water resources as this is dependent on a range of factors beyond the technology in question (i.e., water source, management practices, water usage).

4. Concluding statement

Considerable enhancements are required to Water.org's internal evidence base on climate change. Water.org has a generally weak internal evidence base concerning the effects of WaterCredit programs on the climate resilience of WSS services or the contribution of these WSS services to climatic changes. Indeed, of the five thematic areas investigated for this meta-study, climate change has the weakest internal evidence-base. This largely reflects that climate-related information has not been collected as part of Water.org's ongoing monitoring and WSS data collection activities and has not been a focus of most evaluations. The four recommendations below are offered to help address this issue and improve Water.org programming.

5. Theory of Change

The diagram below depicts the Theory of Change (ToC) for the climate change theme. This represents an initial ToC, and will be further developed during the co-creation workshop for the climate change theme at the beginning of December. The ToC builds from the foundational outcomes (blue boxes) up to the theme-related outcomes (green boxes and other colors from other themes). The ToC shows how change is expected to occur both regarding the WaterCredit (blue arrows) and WASH contributions (black arrows). It also maps out the linkages between related outcomes, the level of impact associated with these connections, and the strength of evidence associated with each outcome, as explored in the report (please see the key for further detail).

Figure 15. Key for the ToC

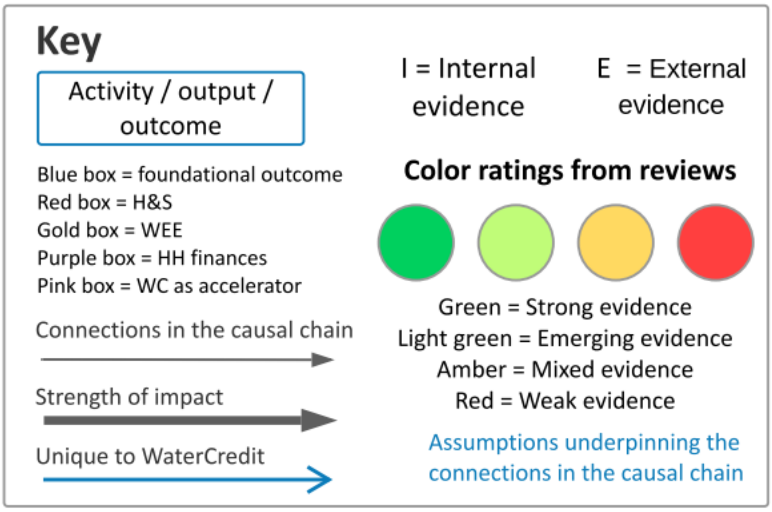
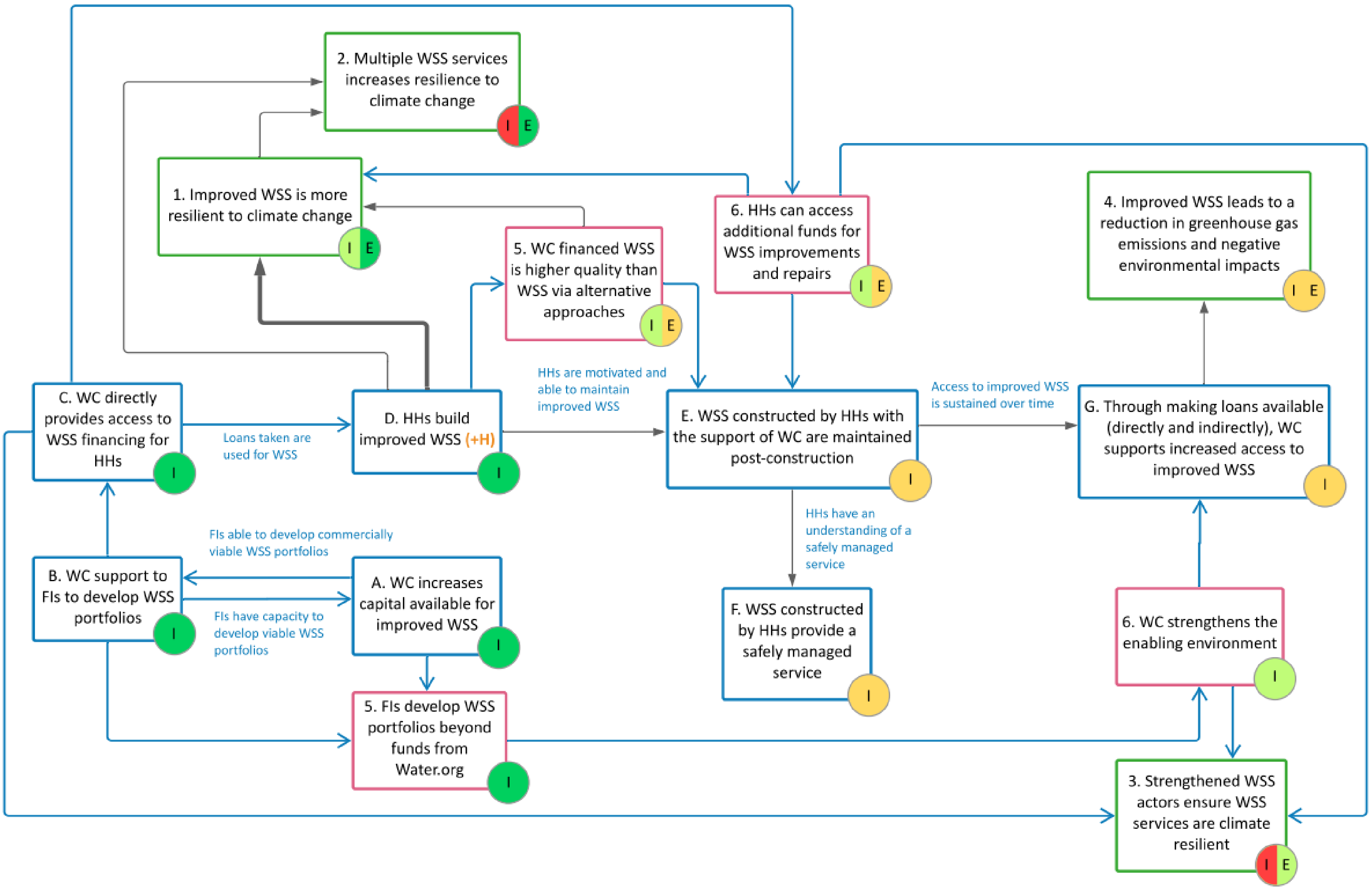


Figure 16. Draft ToC for the climate change theme



6. Recommendations

Adopt a climate lens to WaterCredit programs and support partner MFIs in their programming to increase the climate resilience of WSS services and reduce GHG emissions and ensure partner MFIs take key steps in this regard. Many WaterCredit programs are implemented in contexts where climate change is having a significant impact – for example, Uganda, Cambodia, Kenya, Tanzania, India, The Philippines, and Indonesia (University of Notre Dame, 2021). Some Water.org partners operating in these countries are starting to take important steps to increase the climate resilience of WSS improvements financed through WaterCredit programs. However, these are currently insufficient, with the Partner Climate Change Survey administered for this study highlighting a clear need for further action. Accordingly, there is critical need for Water.org to adopt a climate lens to its programming and integrate climate strategies into WaterCredit programs and partnerships with MFIs. Key areas where Water.org should prioritize supporting partner MFIs and ensuring action is taken include:

1. Increasing partner MFIs' knowledge of local climate threats and projected climatic changes.
2. Increasing partner MFIs' knowledge of the shocks and stresses associated with local climate threats and project climatic changes and how each of these indirectly impact WSS service provision.
3. Pushing partner MFIs to work with local organizations that supply and / or implement WSS services more resilient to local climatic conditions and threats as well as projected climatic changes.
4. Pushing partner MFIs to work with local organizations that supply and / or implement WSS services that typically have lower levels of energy-use and GHG emissions.
5. Developing tailored guidance for partner MFIs to use in training and sensitization activities with loan recipient households that cover key context-specific climate issues. At a minimum, this should include appropriate infrastructure selection (including factoring in other available WSS services) and key management practices.
6. Facilitating households to purchase climate resilient WSS services through steps such as enhancing the size or terms of WSS loans available for certain technology options.

Ensure key aspects relating to climate resilient water supply and sanitation services are systematically captured in program monitoring survey activities. Water.org has taken some important steps in its program monitoring survey to begin periodically collecting information relating to climate change. However, based on the key climate change related aspects detailed in this thematic report, additional areas exist where the impact of WaterCredit programs on the resilience of households' WSS services and the extent of climatic changes should be further investigated. Table 12 details the climate change focused questions in the survey as well as additional questions and areas for investigation that should be added. Overall, this highlights the need to add additional questions to ensure key aspects such as multiple WSS services and knowledge transfer are captured. Only a few further additions are required concerning resilient WSS services. Additions were deemed not necessary for investigating GHG emissions and environmental impacts as these key aspects could not be reliably investigated through household surveys.

Expand the areas that Water.org partner MFIs are required to provide ongoing data on to include key climate change aspects. Water.org's internal management information system, the WaterPortal captures data on a wide range of indicators, with data submitted on an ongoing basis by partners. This dataset could be expanded to include key aspects that would help to determine the climate resilience of WaterCredit financed WSS improvements. Information that it would be beneficial to capture in WaterPortal include:

1. **Climate Resilience Score.** An automatically generated score denoting the level of climate resilience of WSS infrastructure improvements to current climate threats and projected climatic changes in the local context. For example, each technology could be given a pre-assigned rank from 1-5 for their climate resilience in each context, with these scores being automatically generated and tracked on a per country and per partner basis when new partner MFIs provide new information on infrastructure improvements financed by WaterCredit. This monitoring could also increase partner MFIs' efforts to promote more climate-resilient infrastructure.
2. **Service Providers.** Ensuring partner MFIs provide information on the service providers for water supply and sewered sanitation services as well as the primary actors responsible for each stage of the sanitation service chain. This information must be collected in a manner that makes it easy to aggregate to aid future analysis by. A key step here, for example, would be to ensure service providers are grouped into a typology of arrangements (i.e., community-based organization, local government, small utility, national or regional utility, private operator).

Conduct one-off research activities to establish WaterCredit programs' impact on specific aspects of climate change. Much of the information required to properly evaluate Water.org's impact on the climate resilience of WSS services and climate change cannot be properly collected through Water.org's ongoing monitoring activities through the program monitoring survey or the data collected for WaterPortal. In several instances, more rigorous one-off research activities are required to properly establish the impact of WaterCredit programs on climate-related aspects. One-off studies could be beneficial across all the different sub-themes investigated in this paper: (i) climate resilient WSS infrastructure; (ii) multiple WSS services; (iii) WSS actors; and (iv) GHG emissions and environmental impact. Depending on the purpose of these studies, it is likely appropriate to wait until Water.org has implemented programs with a more explicit focus on climate change before conducting these.

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