Dalberg

Assessing the Climate Resilience of Safe Water Enterprises (SWEs)

FINAL REPORT
MAY 2020

Executive Summary (1/7)

Context & the analysis framework

In recent years, Safe Water Enterprises (SWEs) have emerged as a viable solution to help meet the world's drinking water needs. The 2017 report "The Untapped Potential of Decentralized Solutions to Provide Safe, Sustainable Drinking Water at Large Scale" found SWEs already had a global footprint across Asia, Africa, and Latin America, and were reaching 3 million customers. In addition, the study noted that the potential market size for decentralized water systems was 3.9 billion people. Since then, SWEs have expanded rapidly – for example, 1001fontaines grew more by more than 5 times, and today serves over 700,000 customers in Cambodia alone.

However, climate change is increasingly threatening water supply systems around the world, including SWEs. Climate change is perhaps the largest threat faced by water systems. It manifests as shock (e.g. increased droughts and flooding, more severe storms) and stress events (e.g. depleting groundwater levels, rising oceans), and necessitates that water systems build resilience to guard themselves against potentially devastating effects. In this light, it becomes important to assess the relative resilience of SWEs in the face of climate change and identity measures to improve resilience.

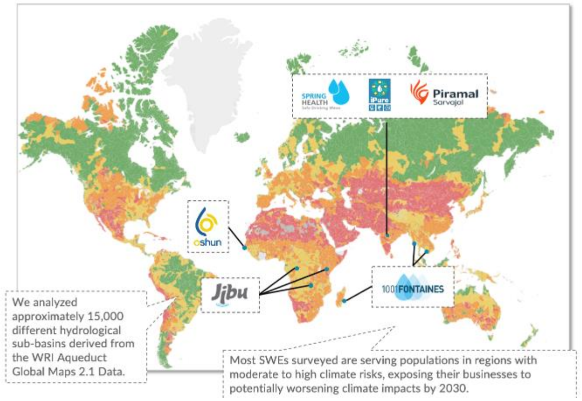
This report, by Dalberg, is a strategic assessment of the climate resilience of SWEs, and also lists key mitigation tactics and implications for funders, policymakers, and SWEs. The framework identifies ~ 23 different pathways through which climate change affects the supply & demand sides of safe drinking water supply. These include some obvious pathways such as increase in groundwater depth but also more non-obvious ones such as reduction in customer density due to out-migration. The report also identifies nine categories of resilience tactics that can be deployed by SWEs including creating larger buffer stocks, moving to alternate treatment technologies, and even sharing resources across locations. Finally, the report makes five big recommendations for the ecosystem including the creation of an SWE-Climate Alliance and the setting up of a climate change resourcing fund for SWEs.

The analysis framework is customized and draws from resilience approaches within energy systems, business systems resilience, and urban water systems. While there is no consensus framework on understanding the climate resilience of water systems, we have identified key concepts and lessons from analysis related to climate resilience for businesses in general and specific adjacent sectors like energy infrastructure. We believe resilience can be understood as a combination of intrinsic resilience – actions that an organization can implement without outside support – and assisted resilience – things that require external support. Together, these resilience measures prevent the organization from experiencing the full effects of climate change. Left unmitigated, climate change may force water systems to reach a point of failure where they are no longer meeting the WHO's safe water parameters for quality, quantity, continuity, accessibility, and affordability. Chapter 3 describes the resilience framework in additional detail.

The report, combining the water climate risk and resilience frameworks, also identify the anticipated effects of climate change on SWE service delivery across the world. The analysis looks at a 10-year timeframe and uses the hydrological basin as the fundamental analytical unit, allowing for highly localized effects to be understood. We have consolidated our findings into seven segments that summarize effects across different regions. Key highlights are listed in the Executive Summary, with Chapter 4 providing additional analysis and details.

Executive Summary (2/7)

Climate-water risk will have widely varying effects for SWEs in different regions; quality and continuity are likely to be most affected



Risk category definitions	Population (in mn) and sample regions
Low risk: Very low current water risk; water levels are expected to remain high and consistent; negligible impact	~500 Iceland, Canada
Low - moderate risk: Water quantity, quality levels are sufficiently high and minimal shift in water stress and/or seasonal variation expected; low impact	~1,800 Democratic Republic of the Congo
Moderate – high risk: Moderate water risk levels (quality, quantity, regulation) and average climate change effects anticipated; moderate impact	~2,800 Madagascar, Eastern India
High risk: High water risk with large shifts expected in both water levels and seasonal variation; highly vulnerable to climate change	~2,300 Haiti, Northern India

Water Climate Risk categories

		Category 1: Low risk	*Category 2: Low - moderate risk*	*Category 3: Moderate – high risk*	*Category 4: High risk*
Total population (millions)		~500	~1,800	~2,800	~2,300
Total opportunity (million) (pop. without access to safe drinking water)		~190	~980	~1700	~1400
Climate risk scores (for each water supply outcome)	Quantity	1	1	3	4
	Quality	2	3	4	4
	Accessibility	1	1	2	3
	Continuity	1	2	3	4
	Affordability	1	3	4	4
Overall Water Risk Score		1.2	2	3.2	3.8

Climate risk score
1=low, 4= high
- Very low
- Low
- Medium
- High

Overall water risk score is an average of the climate risk scores assigned to each WHO water supply criterion; the intent is to give a composite indication of the risk to water supply in each category absent mitigation efforts.

The world can be segmented into four climate-risk regions that vary on the risk that water supply faces due to climate change. A large fraction of the population lives in high-risk or moderate-high-risk regions mostly near the Equator. A large number of people also live in the moderate-low risk region principally in Sub-Saharan Africa, Latin America, and parts of Australia.

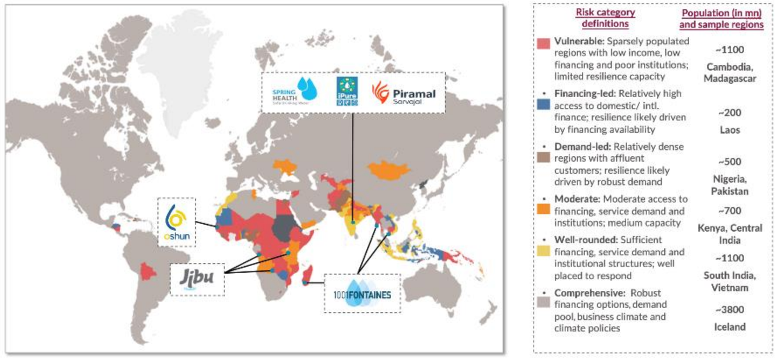
Nearly 5.1 billion people live in regions of the world that are likely to face High or Moderate-High climate risk over the next 10 years. Out of these, 3.1 billion people don't have access to safe drinking water and form the potential customer base for SWEs. A large proportion of this population is concentrated in Asia & Africa with countries such as India accounting for a sizable share of this at-risk population.

Different water supply outcomes, as defined by WHO, face varying levels of risk across these climate regions. Water quality and water affordability are two aspects of water supply that are most at risk in the face of climate change. This is driven primarily by a) Increasing levels of shock events such as flooding that increase water contamination and b) Increasing stress events such as reduction in the groundwater level that increases water salinity. Both of these cause substantial increases to the treatment costs of SWE water systems leading to reduction in water affordability. Water quantity and continuity also are at risk as water levels decrease in both groundwater and surface water due to climate change and stress and shock events reduce uninterrupted water supply for communities.

The High-risk segment, with 1.4 billion people without access to safe drinking water, is likely to be particularly badly affected in terms of water supply outcomes. In this segment almost all water supply outcomes – quantity, quality, continuity, affordability, and accessibility face an extremely high risk due to climate change. It will need proactive measures to ensure water supply in the face of such climate risk. The moderate-high risk segment fares marginally better on parameters of Water Quantity & Continuity.

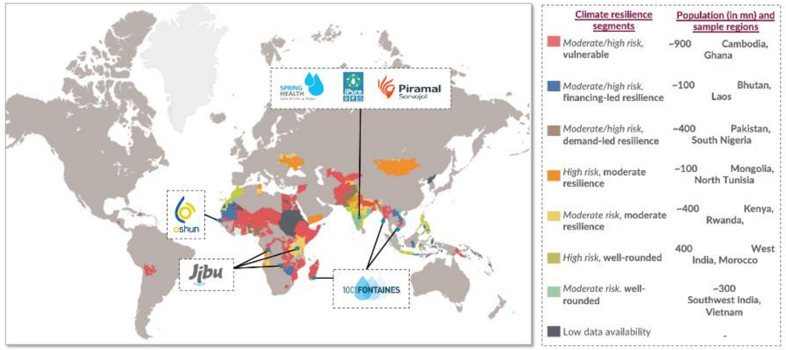
Executive Summary (3/7)

SWEs in about 65% of their target markets will be able to shape a resilience response due to public finance availability or customer willingness to pay extra; the other 35% (the most vulnerable regions) will require special support



Focus of study[1]

Climate resilience segment	Climate Water Risk	Resilience enablers	Definition	Population (millions)	Potential customers (% of total pop.)[2]
Moderate/high risk, **vulnerable**			Most vulnerable regions - medium to high risk of climate change and very little capacity for resilience	~900	83%
Moderate/high risk, **financing-led resilience**			While climate risk is high, water systems in these regions are able to access domestic and/or intl. financing to build resilience. Due to low density and/or income levels, they cannot depend on strong demand when under duress	~100	68%
Moderate/high risk, **demand-led resilience**			While climate risk is high and financing options and institutional support is low, these regions are dense and have high income households; this robust demand likely to be a buffer during climate stress	~400	83%
High risk, **moderate resilience**			Moderate level of resources available to respond to the significant climate change impact expected	~100	77%
Moderate risk, **moderate resilience**			Moderate level of resources available to respond to the medium climate change impact expected	~400	82%
High risk, **well-rounded**			Despite high climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt	~400	74%
Moderate risk. **well-rounded**			Despite moderate climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt	~300	75%
Low/very low			Regions where water levels are high and climate change is unlikely to affect		



In addition to different levels of water climate-risk, regions also have varying levels of the ability to respond to these risks through financial support, institutional strength, or simply consumer demand and this analysis classifies the world into five such categories. As an illustration, "Vulnerable" regions lack both the public or private sector financing and also consumer ability for water systems to spring back in the face of climate change. On the other end of the spectrum, well-rounded regions have the access to financing, consumer demand density, and high-quality institutions to deliver water services in the face of climate shocks and stresses.

Overlaying the resilience enablers on climate-risks, the report classifies the world into seven unique water-climate segments. At one end, the High-Risk/Vulnerable Segment has 900 million people and many parts of SSA/SEA and offers opportunities for seasoned SWE funders who are looking for capital recovery or philanthropic outcomes. On the other hand, the ModerateRisk-WellRounded segment has 400 million people and offers opportunities to impact investors. Other segments lie in-between and offer different challenges and propositions for different categories of funders.

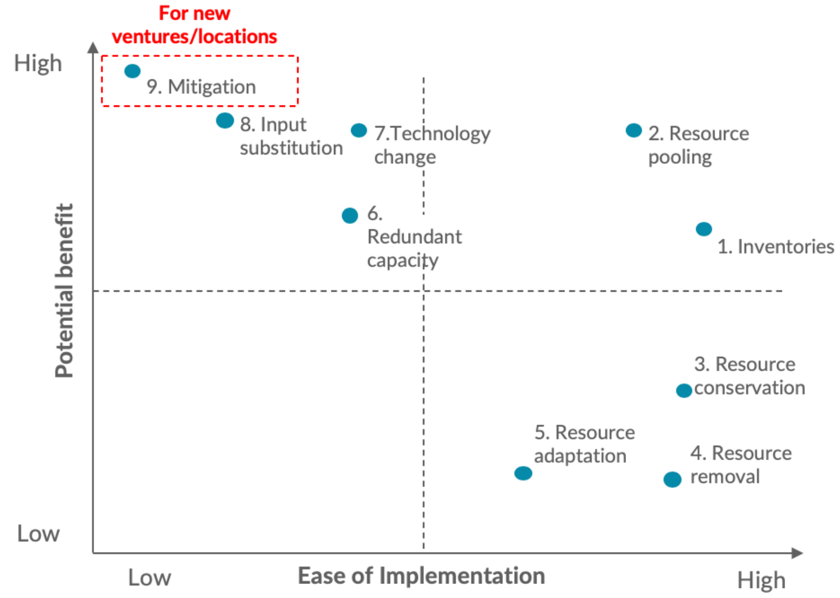
A large potential market exists in regions with moderate to high climate change and a mix of resilience sources (some derive resilience from the demand side as they are located in dense, middle-income areas, while others are in regions where financing is relatively easy to come by). For example, in Kenya and Rwanda relatively dense populations and robust presence of funders will allow for some resilience. In southern Nigeria and Pakistan, most customers will be able to absorb a price increase. These segments together constitute a potential market of **840 million unserved**.

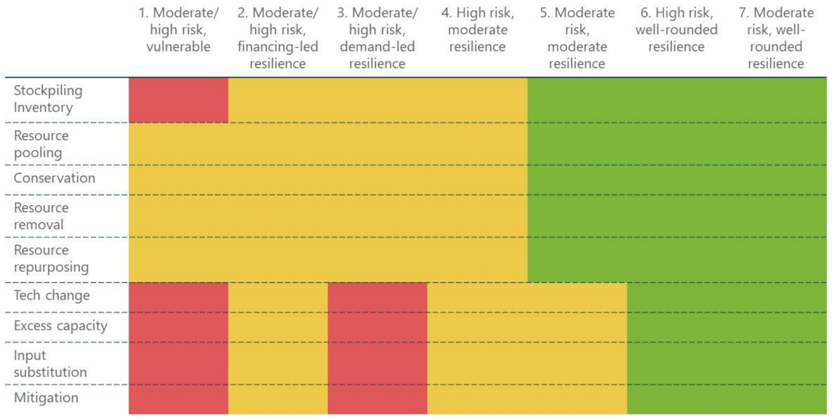
Finally, a number of regions have well-rounded resilience and can respond to climate risk without relying on external support. The segment includes much of southern India, the Philippines, Morocco, and wealthier islands of western Indonesia. The SWE market here is **580 million**, and given the relatively low risk profile we expect **prospective investors and those looking to minimize their exposure to climate risk** to begin their SWE engagement here. It may also be important for existing investors to balance their portfolio, and if they are largely invested in higher risk segments, they may want to make some strategic deployments in these regions.

Note: To focus on markets where the SWE model is likely to be relevant, we have excluded High Income and Upper-Middle Income countries (as classified by the World Bank) in calculating the opportunity size. The seven segments cover a total population of 3.6 billion

Executive Summary (4/7)

Most risks of climate change for SWE performance can be mitigated through nine categories of measures; but implementing these initiatives could drive up cost-to-serve by between 3%-18% based on segment





SWEs are adopting a host of tactics to mitigate climate change's more deleterious effects. Even during times of severe climate shocks, SWEs often continue to offer essential services to their customers. For example, when Maharashtra experienced one of its wettest monsoons ever, Naandi was able to continue supplying safe drinking water.

In this report, we have consolidated tactics already deployed by SWEs and supplemented these with additional potential solutions – in total, the report covers 23 tactics spread across 9 categories. In order of increasing complexity (with the easiest to implement coming first), these response categories are:
1) Inventories: Building excess inventory of both raw & treated water, and other essential supplies, **2) Resource pooling:** Pooling critical resources across SWE locations and with other players in the supply chain, **3) Conservation:** Maintaining intended water production and service levels using lower amounts of production inputs, **4) Resource removal**: Modifying a portion of SWE operations to run without specific process inputs, **5) Resource adaptation:** Modifying existing SWE resources to enable new purposes, **6) Redundant capacity:** Building redundant capacity of key inputs such as energy to keep the SWE running in the face of shocks, **7) Technology change:** Shifting critical technology/ filtration processes for SWEs, **8) Input substitution**: Replacing a key production input in short supply with another (e.g., replacing electricity with natural gas), and **9) Mitigation-oriented design**: Designing infrastructure and processes to mitigate the impact of disruption on primary production processes, especially at the beginning of a new SWE venture.

Two other points are worth calling out

- **Implementing these tactics to remain resilient and to ensure continuous water supply involves both capital and operational expenditures** and we estimate that this will increase cost-to-serve by 3% in the low-risk segments and by as much as 18% in the high-risk segments. More details of this are in the report.
- **Not all water-climate segments will be able to implement all these tactics and ensure 100% resilience.** The figure on the left highlights how most segments will be able to implement only a subset of these tactics independently and will require external support

Executive Summary (5/7)

Funders should become more targeted & collaborative on the one hand and extend more operational support to their investees to tackle climate change; policymakers should integrate SWEs as a valuable tool in their resilience arsenal

Implications for Funders: Climate change will affect SWEs in non-uniform way and becomes an additional variable that funders will need to factor in across their investment lifecycle, from fundraising, to ecosystem building to investing to portfolio company support

Fundraising: To account for the additional variance that climate change brings across segments, funders should look to raise diversified funds that bring together capital with different risk-return goals. Fundraising partnerships with a wide range of "LPs" who are open to the use of derisking tools like hybrid instruments would become critical. Funders should also think of creating sub-funds focused on specific climate-risk regions that offer different risk-return profiles. The good news is that almost all the segments covered in the report have enough of a critical mass.

Ecosystem building**:** To make SWEs (and any other water model) successful in the face of climate change will require coordination across a range of actors in the ecosystem: governments, disaster management agencies, planners. Existing funders should proactively advocate the comparative advantage of SWEs in the face of climate change and advocate for the creation of ecosystem-level entities that can ensure resilient operations, ongoing financing, and also the license to operate for SWEs.

Investing**:** Climate change risk and business dynamics will vary across segments; as a result, targeted, climate-conscious investment will be necessary to ensure investment outcomes align with funder objectives. Investors and other funders should consider portfolio approaches as part of their investment planning process in order to identify funding mixes that meet their needs for creating impact and returns while balancing risk.

Supporting portfolio companies manage climate change**:** Investors should look to create blueprints for climate resilient service delivery and infrastructure that can be shared with and implemented by all investees. In addition, investing in group climate-linked insurance products to provide a financial backstop to support projects experiencing severe, idiosyncratic climate shocks should also be considered.

Implications for Policymakers: Policymakers should look to incorporate climate thinking and the role of SWEs as they analyze their water needs and plan for the future. By building from the water climate risk and resilience framework presented in this report, policymakers can more effectively diagnose how well-prepared their water systems are to meet future needs in the context of a changing climate. Next, policymakers should look to design a comprehensive climate-resilient water supply network, and look for targeted ways to de-risk SWE operations. Finally, policymakers should consider potential collaboration with SWEs for temporary water supply contracts, especially in times of climate shocks where other water systems may be more impacted.

Executive Summary (6/7)

Ecosystem initiatives are a critical complement to SWE-specific investments in order to fully realize the potential of SWEs to provide safe water in the face of climate change; five key ideas can help

Based on the research and the findings outlined above, the report surfaces Five Big Ideas to further prepare SWEs for climate change's looming impacts and better equip them to supply water in the face of climate change:

SWE Climate Alliance / Climate Taskforce In The SWE Alliance: A central secretariat or a coordination organization to enable collaboration among and advocacy by SWEs for climate-oriented purposes. The SWE climate alliance should look to crowd-in resources for building climate resilience, serve as a central coordinating body for the sector (including to host the innovation platform and treatment cost reduction program suggested below), and present a unified SWE voice to policymakers for more effective advocacy in the face of climate change.

SWE Resilience Innovation Platform: A platform to provide space and funding for climate-proofing innovations for SWEs in the buckets identified in this report, and to act as a knowledge hub for climate adaptation. The Platform should look to connect SWEs with innovators from a broader pool (beyond the SWEs themselves) and adapt technologies from adjacent sectors where relevant. Funders can also play a key role in broadening the reach of the platform and connecting SWEs with potential developments in other sectors.

SWE Climate Capacity Resource Fund: A donor-driven fund to provide resources to SWEs for climate adaptations, particularly in low-resource, high-need regions. The Fund should contain two categories for deploying resources – one focused on proactively building resilience capacity and the other on providing emergency funding in extreme scenarios.

SWE Treatment Costs Reduction Program: Program to enable (1) SWE investment in cost-efficient treatment, and (2) research into cost-effective treatment methods. Given that the largest share of expected increase in SWE costs due to climate change is likely on account of treatment costs, this program will allow SWEs to directly focus on this area and for emerging solutions to be rapidly shared and deployed reducing the cost of SWE water for hundreds of millions of people.

SWE Hybrid Financing Network: Network of investors and funders dedicated to providing flexible, impact-oriented funding for SWE climate resilience. The Network will serve as a "clearing house" where potential funders and SWEs come together. This will significantly reduce funding search costs for all actors and allow for easier and swifter funding decisions.

Executive Summary (7/7)

SWEs, Mini-Grids, & Covid-19

With billions of people lacking access to safe drinking water, determining water delivery systems to invest in going forward, in the face of climate change, becomes a critically important question. Sub-optimal choices could result in billions of dollars of investment in systems that don't remain fully functional when climate change related shocks and stresses arrive with varying levels of intensity. Worse still, it could mean that these hundreds of millions of people don't have access to a reliable safe source of water during these events.

This report provides significant new analysis on the question of the climate resilience of SWEs. On the whole, SWEs appear to be a fairly resilient approach through which safe water can continue to be supplied in most regions in the world. While a "comparative" answer would require similar analysis to be carried out for other systems such as piped water networks, this assessment shows that SWEs would perform well and would continue to deliver well on most water supply parameters in most regions except the two worst-affected resource-poor regions that would require external support. In the other regions, with a marginal increase in costs, SWEs could continue to bring high-quality water in line with the WHO guidelines of quantity, quality, continuity, access, and affordability.

Piped mini-grids can also be resilient in the face of climate change and offer high convenience for customers; but are likely to be more expensive because of the upfront connection costs, and also have higher water quality challenges in the face of climate change shock events. While the report does not have conclusive data, the case study on Water4 illustrates how piped mini-grids that rely on a similar decentralized treatment model can be resilient in the face of climate change. However, in the absence of 24x7 water supply, pipes connecting the treatment facility to homes or institutions could get contaminated and are also likely to have higher connection costs.

COVID-19 and similar pandemics pose additional risks for SWEs. COVID-19 has become the singular prism through which resilience of different systems and business models gets viewed. While assessing the Covid-19 risk and mitigation for SWEs would require significant additional analysis, the high-levels of human interaction within the SWE model especially at the point of sale or delivery does pose significant risk both to the SWE staff and to customers. Some low-cost interventions to Covid-proof these touchpoints could include automated filling stations, keeping sanitizer dispensers, and clear plastic partitions at the point of sale.

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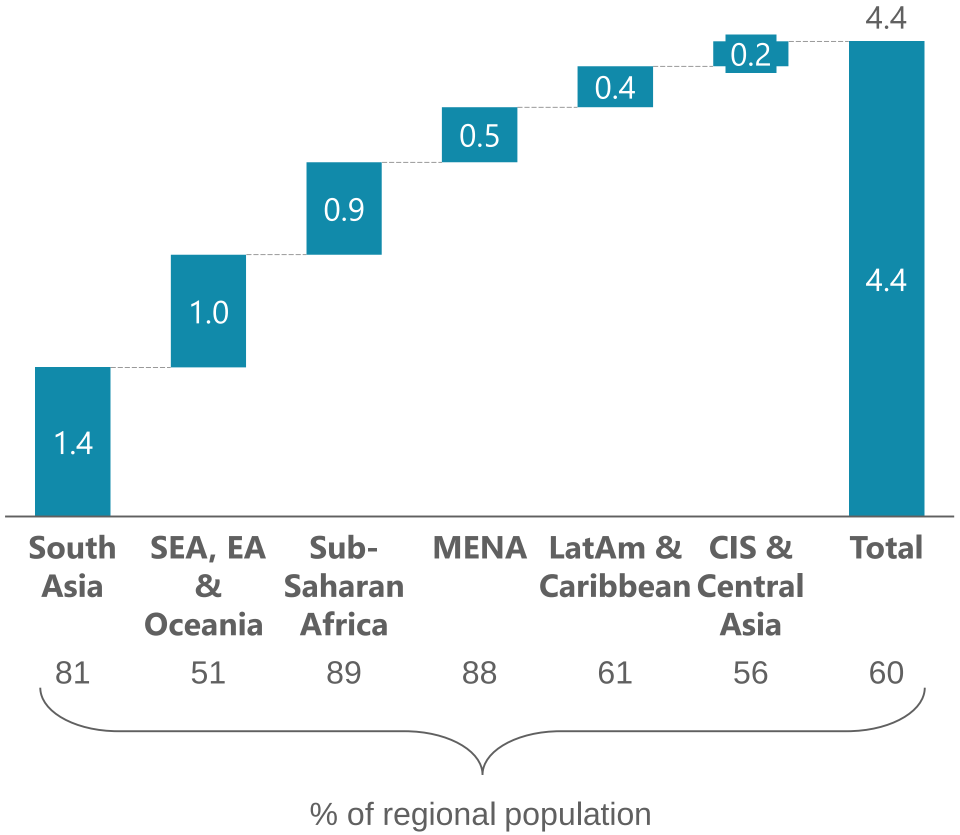
Context: In recent years, decentralized water systems have emerged as a necessary and valuable contributor to the world's potable water needs

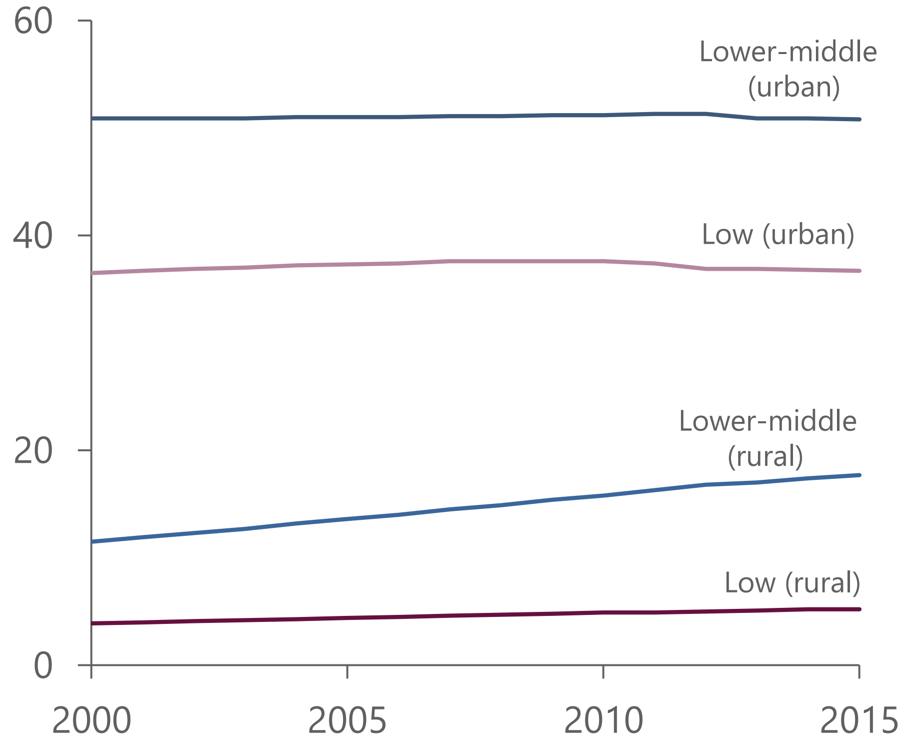
Globally, 4.4 billion people continue to lack access to safe drinking water…

Access to safe drinking water[1]
Number of people without safe drinking water (billions)



…and while piped systems are gradually expanding, such systems alone remain insufficient to meet need

Access to piped water on premises[2]
% of population



Source: 1. IHME, Dalberg analysis (2017), 2. JMP UNICEF/WHO, Dalberg analysis

Context: Previous studies have shown the significant potential of Safe Water Enterprises (SWEs) to benefit those who still lack clean water

Decentralized water systems offer unique advantages that complement other efforts to meet safe water needs…

Reach

Because they are ***significantly less capital intensive*** than comparable piped networks, decentralized water systems can provide service where traditional networks cannot yet serve.

Quality

Even in many regions with piped connection, tap water does not meet safe quality standards; decentralized solutions can provide high quality ***safe drinking water that complements home access***

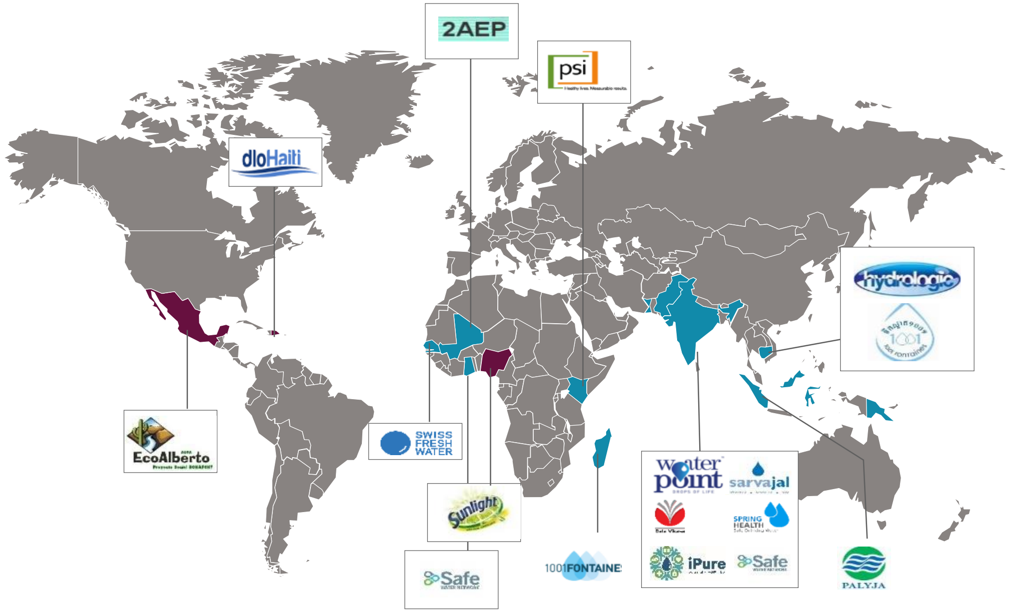
Continuity

In regions where centralized water provision is intermittent, decentralized systems can provide ***continuity of service when alternatives fail***

…and are already serving millions of customers around the world

Prices of Water

Prices reported in 2017 PPP $/20 L (2017)[1]



Source: 1. "SWE Market Report," Dalberg (2017) (all prices were collected by Dalberg from SWEs) 2. PPP Calculations conducted using World Bank "Price Level Ration of PPP Conversion Factor (GDP) to Market Exchange Rate" for 2017.

Context: However, climate change presents serious challenges to further progress on ensuring safe water access for all

As a phenomenon, climate change refers to ***change in global or regional climate patterns***, in particular, a change apparent from the mid-to-late 20th century onwards and ***attributed primarily*** to the ***increased levels of atmospheric carbon dioxide*** produced by the ***use of fossil fuels for human activity***.[1]

The large-scale changes anticipated to result from the process of human-driven climate change will vary from location to location. However, on the whole, they will lead to a range of outcomes with serious implications for the water sector, including:

- Increased ***frequency and severity of droughts*** which can limit water availability and reduce water quality
- Increased ***likelihood of flooding***, which can contaminate raw water supplies and destroy treatment and distribution infrastructure
- ***More frequent severe storms*** like hurricanes, which can pollute raw water supplies and damage infrastructure

The increasing frequency and severity of such events will, through the water ecosystem, impact not only safe drinking water provision but progress towards achieving a host of Sustainable Development Goals, including:

SDG 1: No Poverty

SDG 3: Good Health and Well-being

SDG 5: Gender Equality

SDG 6: Clean Water and Sanitation

SDG 10: Reduced Inequalities

SDG 14: Life Below Water

SDG 14: Life on Land

Source: 1. United Nations Framework Convention on Climate Change, 1992)

Objectives: This study establishes an approach to assess the climate resilience of SWEs

This report is structured around five primary objectives, and concludes with some forward-looking thoughts:

1. Define how ***climate change affects water*** and water supply systems (Chapter 2)
2. ***Develop a framework*** to understand the climate change impacts on and resilience of SWEs (Chapter 3)
3. Conduct *a* ***macro-level analysis*** to determine SWE resilience across different geographic, economic, and social environments (Chapter 4)
4. ***Consolidate climate change implications*** for SWEs and other ecosystem players, including funders and policymakers (Chapter 5)
5. Leverage case studies to ***highlight SWEs' experiences*** dealing with climate change and responding to the climate challenge (Chapter 6)

The framework established as part of this study, although applied here to SWEs, has been designed so as to be broadly applicable to other water systems

Methodology: The analysis in this report was conducted according to the following five-stage process

Stage	1 Climate Hypotheses	2 Segmentation	3 Value Chain Analysis	4 Resilience Assessment	5 Water & Social Outcomes
Key Question	How does climate change ***affect water delivery systems***?	How does the effect ***vary across regions and countries***?	How does climate change ***impact SWE operational and financial metrics***?	How much of this ***impact can be absorbed or mitigated*** by SWEs?	What does the result imply for ***water and social outcomes***?
Summary of Approach	23 hypotheses organized into 3 supply pathways and 4 demand pathways	Globe divided into 9 climate impact segments based on risk and resilience criteria	16 business metrics prioritized across all 4 SWE value chain segments	Operational and financial resilience of SWEs considered according to intrinsic and assisted elements	Climate impacts summarized across 5 WHO water outcomes (Quantity, Quality, Continuity, Affordability, Accessibility)
Data Analyses	• Literature review of global climate change effects • Expert interviews with climate change experts	• WRI Aqueduct Climate Data • World Bank, IMF financial data • World Bank population, income data	• Energy projections • Published academic studies • SWE business operations data • Interviews with experts and SWEs	• SWE impact estimates • Interviews with SWEs • Interviews with climate experts	• SWE business operations data • Interviews with SWEs • Interviews with climate experts

Global Data / expertise   SWE-Specific Data

Methodology: As part of our research, we analyzed data from 20+ global datasets, reviewed literature, and collected inputs from 6 leading SWEs

1 To arrive at a nuanced understanding the global scope of the climate challenge to water systems, we incorporated data from >20 databases, including from resources related to climate, water, social, demographic, economic, and legal-institutional factors.

- Global maps 2.1, "Water risk atlas", World Resources Institute (WRI) (2015)
- Global maps 2.1, "Aqueduct Water Stress projections", World Resources Institute (WRI)(2015)
- "Annual per capita consumption data", World bank (2010)
- "GDP per capita growth (2010-2018)", World bank (2018)
- "Net ODA per capita ", World bank (2018)
- "Gross fixed capital formulation", World Bank (2018)
- "Country credit ratings", S&P, Moody's, Fitch (2019)
- "% population with access to safely managed water", WHO/UNICEF (JMP) (2015)
- "Climate change performance Index", Germanwatch (2019)
- "CPIA policy and institutions for environmental sustainability rating", World bank development indicators (2018)
- "Subnational GNI/capita", UNDP (2018)
- "Gridded global population density", Socioeconomic Data and Applications Center (SEDAC), NASA (2015)
- "National and sub-national ease of doing business rankings", World Bank (2020)
- Dalberg Advisors, "SWE Market Survey" (2017)

2 To situate this understanding within the ongoing conversation around climate resilience, we conducted a thorough literature review of existing academic research on the topic.

- Mariana Beermann, "Linking Corporate Climate Adaptation Strategies with Resilience Thinking," Journal of Cleaner Production (2011)
- Akhtar Hussain, et al., "Microgrids as a resilience resource and strategies used by microgrids for enhancing resilience," Applied Energy (2019)
- Mathaios Penteli et al., "Metrics and Quantification of Operational and Infrastructure Resilience in Power Systems," IEEE Transactions on Power Systems (2017)
- Susan Cutter, "The landscape of disaster resilience indicators in the USA," Natural Hazards (2015)
- Noah Dormady and Adam Rose, "Economic Resilience of the Firm: A Production Theory Approach," International Journal of Production Economics (2018)
- Kees C.H. van Ginkel et al., "Urban Water Security Dashboard," Journal of Water Resource Planning and Management (2018)
- E.H. Krueger et al., "Resilience Dynamics of Urban water Supply Security and Potential of Tipping Points," Earth's Future (2019)
- Linnenluecke and Griffiths, "Assessing organizational resilience to climate and weather extremes," Climatic Change (2011)
- Grasham et al., "On considering climate resilience in urban water security," WIREs Water (2019)
- Dalberg Advisors, "SWE Market Survey" (2017)

3 To further elucidate climate change's particular impact on SWE business operations, we also collected data from 6 leading SWEs in Asia and Africa. Data was collected in multiple forms, including from in-depth semi-structured interviews with senior staff, from responses to emailed climate questionnaires, and from business documents shared with Dalberg by SWEs.

SWEs Surveyed	Location(s)
Jibu	Kenya, Rwanda, Uganda, Tanzania, Zambia, Burundi, and DRC
1001fontaines	Cambodia, Madagascar, Vietnam, and Myanmar
Sarvajal	India
Naandi	India
Spring Health	India
Oshun	Senegal
Water4	Operations in 13 countries[1]

Note: 1. Burkina Faso, Democratic Republic of the Congo, Ghana, Kenya, Liberia, Malawi, Rwanda, Sierra Leon, Tanzania, Togo, Uganda, Zambia, and Peru

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Climate change has two primary effects on the planet's climate: temperature increases and weather (precipitation) pattern changes

Anthropogenic (man-made) climate change refers to "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to the natural climate variability observed over comparable time periods."[1] The major driver of man-made climate changes is the emission of greenhouse gases (GHGs), including carbon dioxide, through human processes.[2] GHGs retain energy in the earth's atmosphere which would otherwise be radiated into space; higher atmospheric GHG concentrations result in more energy being retained in the atmosphere.[2]

The result of this extra energy retained within the earth's atmosphere manifests in two primary changes in the planet's climate: (1) increases in average temperatures, and (2) changes in established, prevailing weather patterns.

Increases in average temperatures

Globally, the increasing concentration of GHGs in the atmosphere has resulted higher air, water, and land temperatures.

- **Air:** Global average air temperature has increased by 1.1°C since the pre-industrial period; 20 of the 22 warmest years ever recorded occurred in the last 22 years.[3]
- **Ocean:** Upper ocean temp has increased by 1.3°C over the past century, with 3 of last 5 years clocking the highest ever recorded oceanic heat content.[4,3]
- **Land:** Average annual land surface temperature has increased by 0.8°C from the long-term average; 2 of last 4 years were the hottest ever recorded.[5]

Changes in established weather patterns

Across regions, the established weather patterns on which human settlements have been premised are rapidly changing.

- **Rainfall is increasingly variable.** While some regions like Northern Russia and Southwest Asia now receive abnormally high precipitation, others like India and Australia experience more long-term droughts.[3]
- **Extreme weather events are becoming more common.** As the globe warms, storms, hurricanes, and heavy rainfall events are increasing in frequency and magnitude. For example, the number of floods annually has quadrupled since 1980.[6]

Note: a. Land temperature refers to the
Source: 1. UN Framework Convention on Climate Change;. 2. Climate Science Special Report, US Global Change Research Program; 3. The WMO report on The Global Climate in 2015-2019; 4. IUCN 5 NOAA Global Climate Summary 2019; 6. "Extreme weather events in Europe: Preparing for climate change adaptation"

These changes to the climate affect the supply of and demand for safe drinking water through 7 distinct pathways…

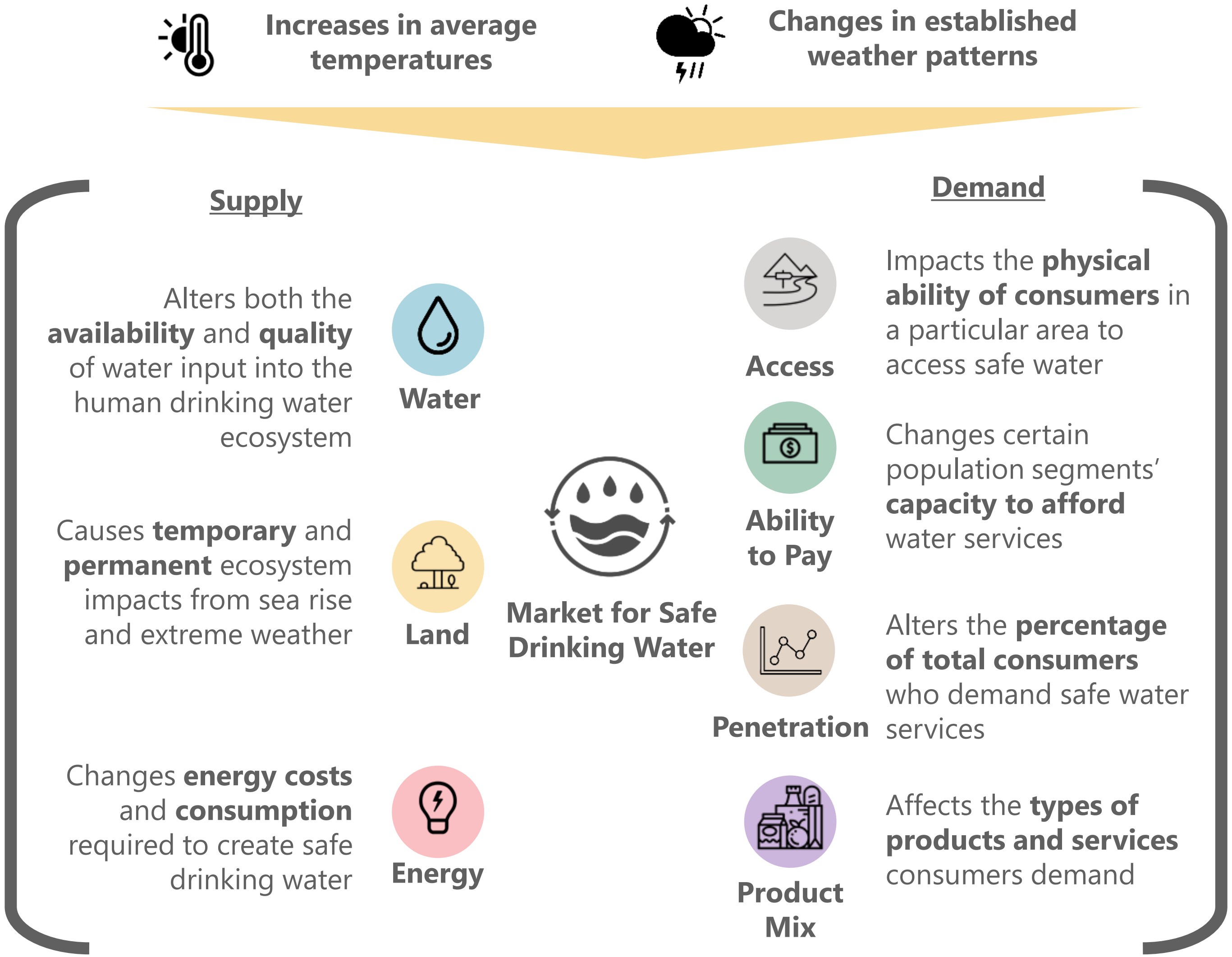
Climate change impacts the market for safe drinking water on both the supply and demand sides.

<u>**Supply**</u>: Climate change impacts safe water supply through three key input factors necessary for the production and distribution of safe drinking water.

- <u>Water</u>: Raw water is the primary input into the production of safe water. Climate change impacts both quality and quantity of raw water in a location.
- <u>Energy</u>: Significant energy is required to refine and distribute safe drinking water. Climate change will change both the price and quantity of inputs required.
- <u>Land</u>: Safe drinking water must be transported across physical space from treatment point to the consumer. Climate change disrupts existing systems capacity to distribute water through temporary (e.g., floods) and permanent (e.g., sea level rise) means.

<u>**Demand**</u>: Four key elements of consumer preferences and habits channel climate impact on demand for safe water.

- <u>Access</u>: Climate change disrupts physical spaces (e.g., storms), limiting consumers ability to access water.
- <u>Ability to Pay</u>: In many regions, consumers ATP will be reduced by climate change's livelihood impacts.
- <u>Penetration</u>: For-profit water suppliers rely on high penetration to achieve sustainability; climate change-induced changes can impact penetration rates.
- <u>Product mix</u>: As the climate changes, consumers may demand different products.



…that we used to identify a set of 23 hypotheses specifying particular means through which water systems are likely to be impacted (1/2)

Increases in average temperatures | **Changes in established weather patterns**

Water

Availability

1. Change in precipitation quantity causes changes in freshwater availability
2. Ice melt causes changes in short (increased) and long (decreased) term water availability
3. Erratic precipitation causes change in freshwater availability

Quality

4. Rising sea levels lead to salination of groundwater
5. *Extreme weather like flooding causes contamination of existing water sources*
6. *High freshwater temperature causes algal bloom leading to oxygen reduction*

Land

Temporary effects

7. *Extreme weather causes disruption to transportation infrastructure, treatment plants, distribution routes and delivery infrastructure (e.g., kiosks/ATMs)*

Permanent effects

8. Decrease in water freshwater quantity / quality causes change in location of water extraction
9. Rising sea levels cause inundation of coastal regions and lead to permanent displacement of infrastructure

Energy

Energy cost

10. Shift to climate-friendly energy policy causes energy prices to increase
11. *Extreme weather events lead to power supply disruption*

Energy consumption

12. Water table depletion necessitates more energy for extraction
13. Water quality degradation causes wear and tear leading to more energy required for transportation
14. Water quality degradation necessitates more energy for treatment
15. Increased temperature leads to higher baseline electricity consumption (e.g. air conditioning)

Stress = Plain Text   *Shock = Italic Text*

...that we used to identify a set of 23 hypotheses specifying particular means through which water systems are likely to be impacted (2/2)

Increases in average temperatures

Changes in established weather patterns

Access

16 *Rising sea levels lead to inundation of coastal regions and mass migration, making some services inaccessible or unusable*

17 *Extreme weather like flooding, droughts, drying of surface water resources, etc., cause services to become temporarily inaccessible or unusable*

Ability to Pay

18 *Change in precipitation patterns alter livelihood opportunities (e.g. some crops become unviable), changing local area income levels*

19 *Extreme weather like droughts/cyclones, along with climate-induced ecosystem events (e.g., locust plagues) temporarily affect customers' income*

Penetration

20 *Population shift from displacement changes consumer density and segmentation, leading to fluctuating penetration rates*

21 *Variable precipitation patterns cause failure of alternative water sources, leading to higher demand on remaining accessible resources*

Product Mix

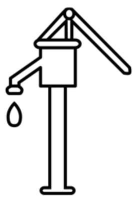
22 *Change in reliability and cleanliness of alternatives induce consumers to use SWE products for alternate uses (e.g., cooking)*

23 *Changed conditions (e.g., warmer temperatures) induce consumers to demand different products (e.g., refrigerated water) or different quantities (e.g., larger subscriptions)*

Stress = Plain Text *Shock = Italic Text*

From the perspective of an SWE, these effects are mediated through the value chain for safe drinking water…

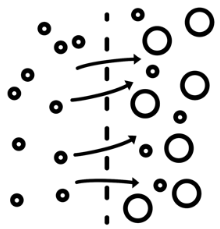
Extraction



At the extraction stage, raw untreated water is extracted from one of several typical sources, including:

- Groundwater (borewells, springs)
- Surface/rain water (open wells, ponds, spring water, or reservoirs)
- Utility water (piped connections)
- Sea water (reservoirs, canals, or borewells)

Treatment



At the treatment stage, chemical and bacterial pollutants are removed from raw water in order to produce safe, potable water for human consumption. Typically, SWEs utilize one of several methodologies to treat raw water:

- Reverse osmosis (RO)
- Chlorination
- UV Disinfection
- Sand filtration
- Micro/ultra filtration

Distribution

At the distribution stage, treated water is packaged and distributed to consumers via one of several delivery models:

- Pick up (customers come to the store)
- Direct home delivery by vehicle
- Delivery to a reseller by vehicle
- Mini-grid distribution

These services typically include cleaning and disinfection of reusable jugs which are purchased from the company by the consumer.

Payment

At the distribution stage, treated water is packaged and distributed to consumers via one of several delivery models:

- Cash on delivery
- Pre-paid
- Monthly subscription

…and impact business processes at distinct stages of production

Value chain specific

Extraction	Treatment	Distribution	Sale
1 Change in total precipitation quantity causes changes in freshwater availability 2 Ice melt causes changes in short (increase) and long (decrease) term availability 3 Erratic precipitation causes change in freshwater availability 8 Decrease in water quantity/ quality causes change in location of water source 12 Water table depletion necessitates more energy for extraction 13 Water quality degradation causes wear and tear leading to more energy in transportation	4 Rising sea levels lead to salination of groundwater 5 Extreme weather like flooding causes contamination of existing water sources 6 High freshwater temperature causes algal bloom leading to oxygen reduction 14 Water quality degradation necessitates more energy for treatment	16 Rising sea levels lead to inundation of coastal regions and mass migration, making some services inaccessible or unusable 20 Population shift from displacement changes consumer density and segmentation, leading to fluctuating penetration rates	17 Extreme weather like flooding, droughts, etc. cause services to become inaccessible or unusable 18 Change in precipitation patterns alter livelihood opportunities, changing local area income levels 19 Extreme events temporarily affect customers' income 21 Variable precipitation causes failure of alternatives, leading to higher demand on remaining resources 22 Change in reliability and cleanliness of alternatives induce consumers to use SWE products for alternate uses 23 Changed conditions induce consumers to demand different products or different quantities

Cross-cutting

7 Extreme weather causes disruption to transportation infrastructure, treatment plants, distribution routes and delivery infrastructure
9 Rising sea levels cause inundation of coastal regions and lead to permanent displacement of infrastructure
10 Shift in policy towards renewable sources leads to price pressure on traditional energy production
11 Extreme weather events lead to power supply disruption
15 Increased temperature leads to higher baseline electricity consumption

Supply **Demand**

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To develop our framework, we reviewed the literature on climate change resilience and identified three key strands of relevant work

There is a rich academic and practice-oriented literature on climate change and resilience

Key sources are listed below, with complete list provided in the Appendix.

Author	Title
Cutter, S	The landscape of disaster resilience indicators in the USA
Dormady et al.	Economic Resilience of the Firm: A Production Theory Approach
Pantel et al.	Metrics and Quantification of Operational and Infrastructure Resilience in Power Systems
Van Ginkel et al.	Urban Water Security Dashboard: Systems Approach to Characterizing the Water Security of Cities
Krueger et al.	Resilience Dynamics of Urban Water Supply Security and Potential of Tipping Points
UNDP	Disaster resilience measurements: Stocktaking of ongoing efforts in developing systems for measuring resilience
WHO, DFID	Vision 2030: The resilience of water supply and sanitation in the face of climate change

There is no standard framework on decentralized water systems resilience, but there are lessons from other frameworks

Key lessons from adjacent frameworks

Climate resilience framework for businesses[1]

- The first step in developing resilience is **understanding vulnerability** – what is the nature and likelihood of climate risks? Next, determine if there will be a **massive discontinuous change** or simply incremental change.
- The response can be **proactive or reactive**. The former is a set of actions taken *before the climate change event* to reduce its impact, while the latter is *undertaken post hoc* in response to the event.

Climate resilience framework for power systems[2]

- Climate impact will have an **intertemporal dynamic** – the initial, major impact on a power system, followed by some period of being in a degraded state, and finally restoration.
- The total impact on the power system is a **combination of reducing the immediate felt effect and the speed of recovery.**

Climate resilience framework for water systems[3]

- The PSIR (Pressure-State-Impact-Response) framework was developed to look at water security issues of cities at a systems level.
- Environmental pressures lead to changes in the state of water parameters which has impact on water supply metrics and necessitates a range of responses from institutions, planners, and operators.

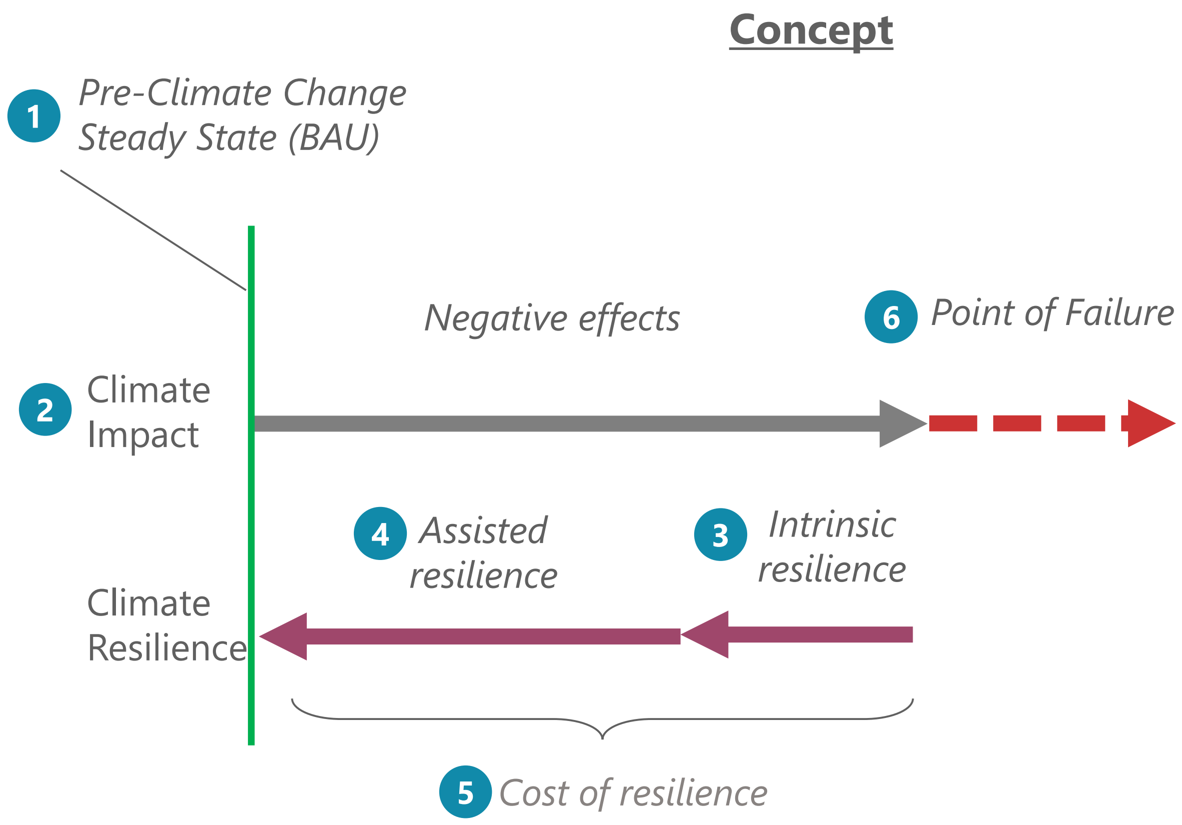
1. Business frameworks adapted from Beerman (2011), Winn et al (2011), and Dormady et al (2018)
2. Power systems frameworks adapted from Panteli et al (2017)
3. Urban Water Security Dashboard: Systems Approach from van Ginkel et al. (2018)

We have reviewed relevant literature and synthesized key concepts that can be used to build a water system resilience framework

Key concepts from the literature...	...distilled and adapted for our context
Static vs. Dynamic resilience **Reactive vs. Proactive** resilience	***Intrinsic resilience*** refers to the ability to respond to unexpected changes based entirely on existing resources and know-how. For SWEs, intrinsic resilience is the set of actions they can take without funding or technical support from investors, governments, or other actors. ***Assisted resilience*** is the set of responses that requires external support in the form of financing or technical assistance.
Tipping points **Massive discontinuous change**	***Point of failure*** refers to the threshold beyond which a business can no longer achieve its primary objectives. In the case of SWEs, this refers to no longer providing safe drinking water.
Vulnerability assessment Identify tactics through **production theory approach**	***Mitigation tactics*** are the set of resilience activities that an organization can implement to protect itself against climate change risk. These begin with a vulnerability assessment to identify where it should focus.

We have approached resilience from a long-term perspective because in developing country contexts, short-term solutions are disproportionately costly

Bringing key concepts together, we have developed a generalizable framework to understand the climate resilience of water systems



1. **Steady State**: The ability of a system to *deliver water that meets the WHO Water Safety parameters* of quality, quantity, continuity, accessibility, and affordability.
2. **Climate Impact**: The *shifts from steady state potentially engendered by the effects of climate change, if left unmitigated*. In the context of safe water, climate impact refers to climate change's impacts on WHO safe drinking water parameters of quantity, quality, continuity, accessibility, or affordability.
3. **Intrinsic resilience**: Response to climate change effects using *capacity already built into the system*. The greater an SWEs financial resources and technical know-how, the greater its intrinsic resilience.
4. **Assisted resilience:** Adaptation to climate change effects using *external support* in the form of financing or knowledge
5. **Cost of resilience and tactical implications:** The *total cost of resilience tactics* deployed to return to steady state. Chapter 4 provides a set of tactics that SWEs can deploy to build resilience.
6. **Point of Failure**: The point at which *a system is incapable of mitigating for marginal climate impact* to return to steady state. In the context of safe water, a point of failure refers to the inability to meet WHO safe drinking water parameters of quantity, quality, continuity, accessibility, or affordability.

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To arrive at SWE climate resilience, our analysis assigns scores for water climate risk and resilience to each hydrological basin

Water climate risks

An SWE's climate risk will be determined by ***aggregate local climate risk factors***, including (non-exhaustive):

- Increased frequency and severity of **extreme weather events** (storms, floods, droughts)
- Impact of **sea level rise** (flooding, groundwater salination)
- Change in **established precipitation patterns** (changing wet and dry seasons, altered precipitation quantities)

Resilience enablers

An SWE's climate resilience will be enabled by three types of ***external features of the SWE's local community:***

- Financial ecosystem (e.g., availability of finance
- Market vibrancy (e.g., demand factors)
- Institutional support (e.g., regulatory risk)

Comprehensive SWE Climate Resilience Analysis

The comprehensive climate resilience analysis considers both of these inputs to derive a meaningful understanding of SWEs' exposure to climate change

Water climate risks

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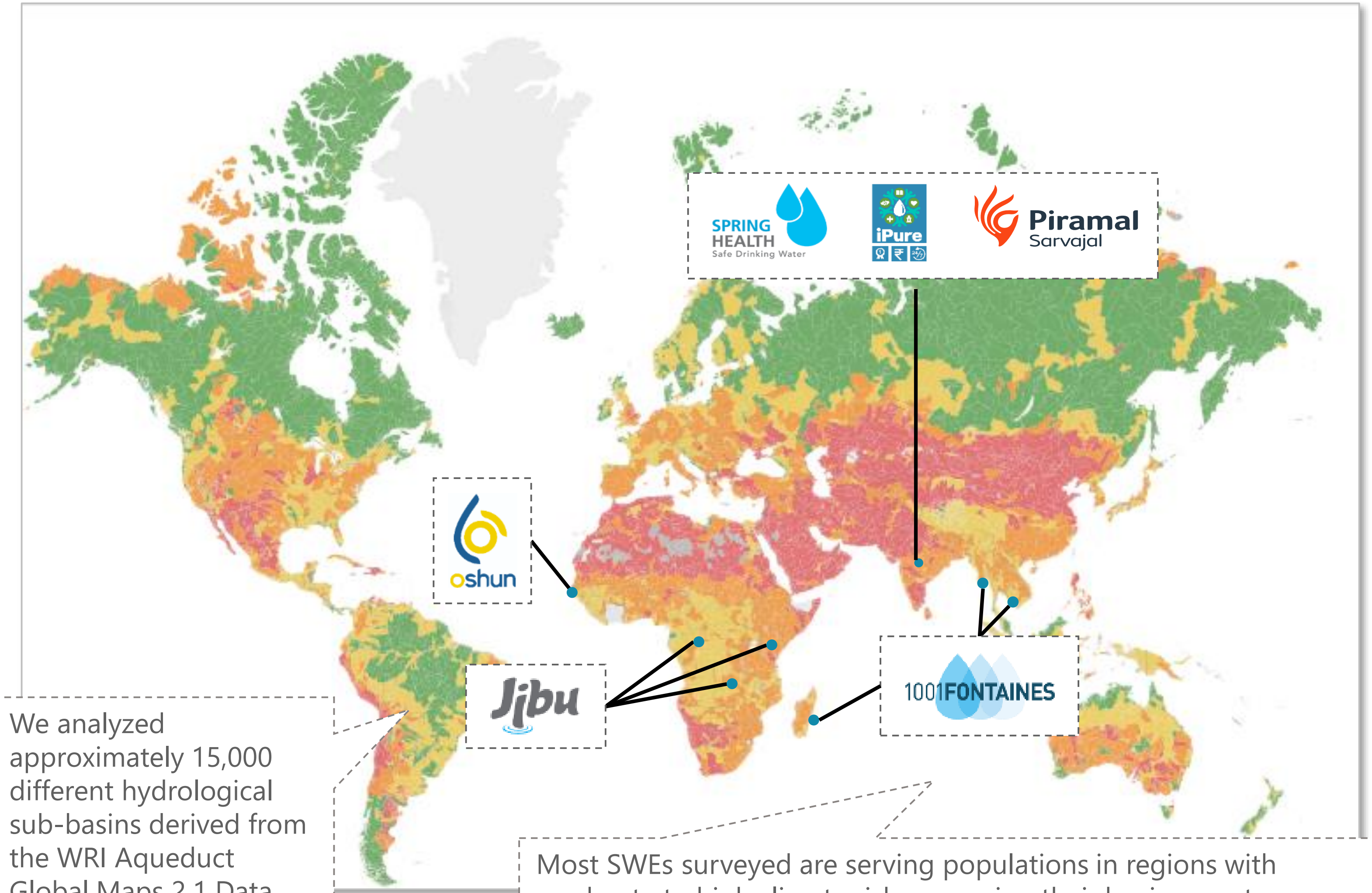
Comprehensive SWE Climate Resilience Analysis

The comprehensive climate resilience analysis considers both of these inputs to derive a meaningful understanding of SWEs' exposure to climate change

While some northern areas have low risk, many densely-populated developing regions face moderate to high water risk from climate change



We analyzed approximately 15,000 different hydrological sub-basins derived from the WRI Aqueduct Global Maps 2.1 Data.

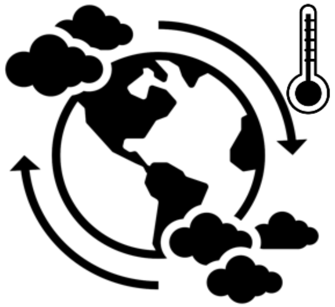
Most SWEs surveyed are serving populations in regions with moderate to high climate risks, exposing their businesses to potentially worsening climate impacts by 2030.

Risk category definitions	Population (in mn) and sample regions
Low risk: Very low current water risk; water levels are expected to remain high and consistent; negligible impact	**~500** **Iceland, Canada**
Low - moderate risk: Water quantity, quality levels are sufficiently high and minimal shift in water stress and/or seasonal variation expected; low impact	**~1,800** **Democratic Republic of the Congo**
Moderate – high risk: Moderate water risk levels (quality, quantity, regulation) and average climate change effects anticipated; moderate impact	**~2,800** **Madagascar, Eastern India**
High risk: High water risk with large shifts expected in both water levels and seasonal variation; highly vulnerable to climate change	**~2,300** **Haiti, Northern India**

Source: WRI Aqueduct Global Maps 2.1 Data; Dalberg analysis

Each climate risk category quantifies distinct climate change impacts on SWE business metrics and consumer-facing water supply parameters

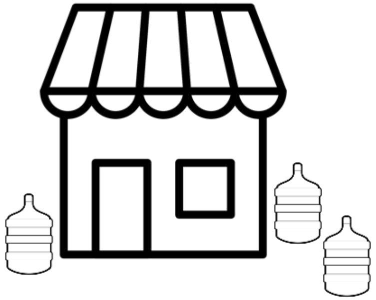
The climate change effects within a river basin…



As human activity changes the climate, these transformations manifest in different geographies in different ways.

We have utilized desk research, data analysis, as well as interviews with leading climate experts ***to estimate the expected magnitude of key climate change impacts on the water ecosystem*** across 23 impact hypotheses (see Chapter 2).

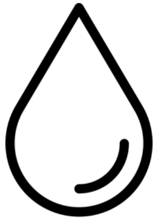
…impact SWE business metrics…



For an SWE, climate change effects manifest as tangible impacts on business operations and financial performance: e.g., a dropping water table necessitates higher expenditures on electricity for extraction.

In order to quantify the impact of climate change on individual SWE business metrics, we have used desk research ***to translate environmental impacts into expected changes in 16 SWE business and financial metrics***. We further validated these top-down estimates with ***information and data collected from 6 SWEs***.

…which in turn implicate safe water parameters



Left unmitigated, changes in SWE business parameters would in turn affect the ability of SWEs to provide safe drinking water to local communities.

To capture this risk, we combined impacts across business metrics to ***estimate outcomes along five drinking water parameters defined by the WHO***: quantity, quality, continuity, affordability, and accessibility. Water quality parameters are assessed on a ***scale of 1 (very low climate impact) to 4 (high climate impact)***.

We prioritized 10 of the most relevant business metrics to determine climate change's overall effect on water supply outcomes for SWEs

SWE business metrics impacted by climate change

Business metric	Value chain	Type
Factor downtime [# of op. hours]	E T D	Operational
Energy for extraction (units/L)	E	Operational
Energy unit costs ($)	E T	Financial
Asset depreciation (%)	E T D	Financial
Cost of chemical ($/L) (groundwater)	T	Financial
Cost of chemical ($/L) (surface water)	T	Financial
Energy for treatment (units/L) (groundwater)	T	Operational
Energy for treatment (units/L) (surface water)	T	Operational
Labour hours for distribution (hrs/L.)	D	Operational
Labour cost for distribution ($/L)	D	Financial
Quantity of fuel (L/Lw.)	D	Operational
Unit cost of fuel ($/Lw)	D	Financial
Quantity demanded (L/person)	S	Operational
Population density (people/sq. mi)	S	Operational
Temporary displacement (days/year/person)	S	Operational
Willingness to pay ($/L)	S	Financial

E Extraction
T Treatment
D Distribution
S Sales

Financial metric
Operational metric

Effect on water supply outcomes

*Climate change is expected to have a significant impact on SWE operations, which is assessed across **5 WHO water parameters contextualized for SWEs***

Definitions

Quantity	Quantity of water available for SWE production
Quality	Quality of water produced by SWEs
Accessibility	% population able to access SWEs for safe drinking water
Continuity	# hours of continued operation for an SWE
Affordability	% population with the ability to afford SWE product

*As the effect of climate change will vary by location, impact has been calculated for each water climate risk segment separately. The effect is assigned a **score on scale of 1 (steady state) to 4 (point of failure)***

Scores

1	2 3	4
Steady state	**Moderate to high risk**	**Point of failure**
Low impact of climate change on SWE operations; nominal change in parameters	Some impact of climate change expected; adaptation necessary for shift back to steady state	Severe impact; left unmitigated, effects could render the SWE operations unviable

The following slides detail climate impacts on SWEs for each climate risk category.

Within the ***high risk*** category, all water parameters except Accessibility are likely to reach point of failure without mitigation

2.3 Bn	63%	North Africa, Central Asia, North & Central China, North India
Population covered	Population % unable to access safe drinking water	Sample regions covered

Key Climate Change Risks

Most **currently face extremely high water stress;** increased demand and over-exploitation expected to **more than double water stress** for a quarter of the segment by 2030

>10% shift in established weather patterns likely within ~15% of the segment, with some experiencing an increase as **high as 300%; frequency of severe droughts** is also expected to as **double by 2030** in some areas

Further **biological, chemical and physical contamination** expected in areas with an already **high water quality risk;** South Asia witnesses the highest risk currently, and is expected to remain high

Key SWE Business Implications

Treatment costs expected to **increase by 32%+** driven by rapid degradation in water quality. **Extraction costs** also expected to **increase marginally (<1%)** due to higher energy requirements for deeper wells

Piramal Sarvajal: *Sarvajal has equipped kiosks with IoT sensors to provide real time raw water TDS levels as this affects treatment costs e.g., >5,000 PPM TDS requires purchasing an additional membrane*

Downtime expected to as much as double sue to disruptions to operations from extended dry days and extreme weather events. These could also lead to a **>4% increase** in **labour hours**

Piramal Sarvajal: *Long and severe droughts lead to temporary shutdowns and even re-location. This prompted Sarvajal to invest in an aquifer recharge project resulting in >2 lakh ltrs of recharge (>80% of withdrawal volume) (Madhya Pradesh, India)*

Water Supply Implications

4 **Quantity:** Doubling water stress and changing seasonal variability will reduce capacity of SWEs to meet quantity demanded without mitigation

4 **Quality:** High risk areas will see significant quality declines due to falling groundwater tables, increased flooding contaminating surface water, driving up treatment costs

4 **Affordability:** Higher operating costs and a sizeable fall in local incomes will put pressure on SWEs' business models; population able to afford SWE product to dip by ~20%

3 **Accessibility:** <1% of population expected to move from high risk areas due to slow onset climate risks

4 **Continuity:** Climate shock events like storm and drought will result in a ~2% annual decrease in SWE annual hours of operation; however, downtime is likely to cluster during extreme weather events

Within the ***moderate-high risk*** category, Quality and Affordability are likely to reach point of failure if left unmitigated

2.7 Bn	60%	Laos, Madagascar, Eastern India, Southeastern China
Population covered	Population % unable to access safe drinking water	Sample regions covered

Key Climate Change Risks

Water stress is **high** for around a quarter of the segment, with **>40% increase expected** in the next 10 years indicating higher anticipated competition for water use

Half of the segment with **extreme seasonal water variation; 10%** of the segment **expecting >1.1x increase** by 2030; highly **prone to floods** with the highest historical flood frequency among segments

Further **biological, chemical and physical contamination** expected in areas with an already **high water quality risk;** Key risks include contamination due to flooding and wastewater discharge

Key SWE Business Implications

Treatment costs expected to **increase by ~20%** driven by rapid degradation in water quality. **Distribution costs** to **increase by ~3%** driven by additional labour support and protective gear needed during extreme events

Jibu: *Water quality decline had major cost implications for Jibu, requiring add on components ($500) or even a complete system swap ($13K); Also, extreme weather events requires buying extra equipment (e.g., roofing/vehicle costs $200)*

Events like **floods, droughts, storms etc.** expected to have an impact on SWE operations. **Severe instances** can even lead to **permanent suspension of operations. Labour hours** expected to increase by ~**3%**

Jibu: *Severe and frequent flooding near Jibu's kiosk locations resulted in the closure and relocation of two of its franchisees (Rwanda, Africa)*

Water Supply Implications

3 **Quantity:** 40% increase in water stress and 10% increase in local seasonal variation will result in significant seasonal shortages in raw water

4 **Quality:** Declines in water quantity and increases in seasonality will result in sizeable seasonal water declines requiring additional treatment technology and expenditure

4 **Affordability:** Higher operating expenses and lower local income will put pressure on SWEs' business models; population able to afford SWE product to dip by ~16%

2 **Accessibility:** Impact to accessibility will be limited. <1% of the population expected to move from high risk areas due to slow onset climate risks; occasional physical disruptions from floods

3 **Continuity:** A still-sizeable increase in climate shock events (storms and droughts) will likely result in a 1.6% decrease in SWE annual hours of operation

Within the ***low-moderate risk*** category, Quality and Affordability water parameters are the most affected

1.8 Bn	54%	Democratic Republic of Congo, Southern Brazil
Population covered	Population % unable to access safe drinking water	Sample regions covered

Key Climate Change Risks

Relatively lower stress on water supply availability; increase in water demand to put pressure on current water sources leading to **>1.2x increased stress** in **only some high risk pockets**

Moderate change (~**10% shift**) in seasonal supply expected, concentrated in the riskiest parts; The **shift in intermittent water availability** is currently the highest in **South Asia and Sub-Saharan Africa**

Currently, water supply in most areas have a **moderate water quality risk,** with some instances of groundwater contamination; quality risk in these areas expected to remain moderate

Key SWE Business Implications

Treatment costs expected to **increase by >15%** driven by moderate degradation in water quality. **>2% increase in employee cost** driven by increased delivery and maintenance to adapt to climate shock/stress event

SPRING HEALTH Safe Drinking Water

Rapid decline in water quality required Springhealth to switch filtration systems, result-ing in a temporary cost increase (Odisha, India)

Only SWEs present in the **more vulnerable pockets** expected to witness high **operational disruptions**. An increase in **temporary displacements of customers also expected** with an uptick in severe weather events

SPRING HEALTH Safe Drinking Water

Springhealth have witnessed a sharp spike in power supply disruption in their kiosks during heavy monsoons (Odisha, India)

Water Supply Implications

1 **Quantity:** Minimal impact on quantity of water available because of low competition in most areas; low impact on SWE expected

3 **Quality:** Water quality expected to moderately decline; the resulting dip in quality requires additional treatment technology and expenditure

3 **Affordability:** Limited climate change effects will still moderately lower incomes and increase operating costs; as a result, the % of the population able to afford SWE product to dip by ~11%

1 **Accessibility:** Few climate change effects will be of significant magnitude to limit physical accessibility; <1% population expected to move due to climate

2 **Continuity:** Relatively mild shocks, including short droughts and minor floods, will result in ~1% decrease in SWE annual hours of operation

Within the ***low risk*** category, the effect of climate change on water outcomes is mostly minimal

0.5 Bn
Population covered

38%
Population % unable to access safe drinking water

Iceland, Canada, Southern Chile
Sample regions covered

Key Climate Change Risks

Almost all of the segment situated in **low water stress areas**; expected to remain so because of a **relatively rich water supply** and relatively **lower commercial demand** (e.g, lower agricultural requirements)

Water availability is quite **consistent** and has comparatively **low vulnerability to extreme weather** events; slight variation in seasonality is expected in some of the segments

Effect on water quality is expected to remain **low-moderate** in the next 10 years; this is due to **low probability of contamination** via floods, storms etc. as well as lower rate of water table depletion

Key SWE Business Implications

Treatment costs still expected to drive up by ~10% driven by increased chemical and filter costs to compensate for water quality decline. **Minimal impact on extraction costs expected** because the water availability risk is low

Minimal operation disruptions expected, with an increase of **~1% in labour hours** anticipated due to an slight uptick in frequency of extreme weather events

SWEs not usually present in this segment because it largely constitutes of higher income countries

Water Supply Implications

1 **Quantity:** Minimal impact on quantity of water available because of low competition; low impact on SWE expected

2 **Quality:** Low-moderate decline in water quality anticipated; possible implications on SWE costs are ~10%

1 **Affordability:** Minimal climate impacts will have a negligible impact on costs and public ability to pay; population able to afford SWE product to dip by ~2%

1 **Accessibility:** Minimal climate impacts will result in no impact on accessibility of safe water through SWEs

1 **Continuity:** Minimal climate impacts, such as slightly changed weather patterns, will reduce SWE operating hours by <1% annually

Across the world, quality and affordability are the water parameters most likely to be affected by climate change, followed by continuity

During the time frame considered for our analysis – from 2020 until 2030 – ***shock events like floods and cyclones are more likely to disrupt water*** than stress factors like salination due to rising sea levels. These shock events have a significant impact on quality as water sources become contaminated. Since treatment costs are the largest driver of overall costs, as a result the cost to serve rises and affordability falls.

Water Climate Risk categories

		Category 1: ***Low risk***	***Category 2:*** ***Low - moderate risk***	***Category 3:*** ***Moderate – high risk***	***Category 4:*** ***High risk***
Total population (millions)		~500	*~1,800*	*~2,800*	*~2,300*
Total opportunity (million) (pop. without access to safe drinking water)		~190	*~980*	*~1700*	*~1400*
Climate risk scores (for each water supply outcome)	**Quantity**	1	1	3	4
	Quality	2	3	4	4
	Accessibility	1	1	2	3
	Continuity	1	2	3	4
	Affordability	1	3	4	4
Overall Water Risk Score		**1.2**	**2**	**3.2**	**3.8**

Climate risk score

1=low, 4= high

- Very low
- Low
- Medium
- High

Overall water risk score is an average of the climate risk scores assigned to each WHO water supply criterion; the intent is to give a composite indication of the risk to water supply in each category absent mitigation efforts.

Note: A small number of regions with a population of ~58M were not included in the segment due to a lack of reliable data on climate water risk.
Source: Dalberg analysis

Resilience enablers

An SWE's climate risk will be determined by ***aggregate local climate risk factors***, including (non-exhaustive):

- Increased frequency and severity of **extreme weather events** (storms, floods, droughts)
- Impact of **sea level rise** (flooding, groundwater salination)
- Change in **established precipitation patterns** (changing wet and dry seasons, altered precipitation quantities)

Climate water risks

An SWE's climate resilience will be enabled by three types of ***external features of the SWE's local community:***

- Financial ecosystem (e.g., availability of finance
- Market vibrancy (e.g., demand factors)
- Institutional support (e.g., regulatory risk)

Resilience enablers

Comprehensive SWE Climate Resilience Analysis

The comprehensive climate resilience analysis considers both of these inputs to derive a meaningful understanding of SWEs' exposure to climate change

An SWE's resilience (intrinsic & assisted) is a function of the financial, social, and institutional support available; this varies by segments

SWEs will need to leverage a variety of external resources as they seek to plan for climate change, to execute resilience preparations, and to respond to climate-induced events. These resources broadly fall into three categories: (1) financial resources, (2) social resources, and (3) institutional resources.

Financial Ecosystem

The availability of finance in a region will enable SWEs to fund investment in climate preparations and to more effectively respond or repair after climate-induced shocks to business operations.

- Government Funding: As a complementary service provider to other government water services, SWEs can seek to leverage greater government-provided funding in regions where governments have more resources at their disposal.
- International Aid: Aid inflows represent an major source of finance for basic services (including SWEs) in many developing regions
- Private Sector Investment: Countries with higher fixed capital formation, SWEs are more capable of raising funding on capital markets.

Market Vibrancy

Demand-side elements of the SWE's operating region influence an SWE's capacity to generate funds for climate investments through sales and to continue operations in the event of a crisis.

- Population density: SWEs require a certain volume of regular customers in order to cover costs and succeed as a viable business model. As most SWEs deliver water to local regions only, those operating in regions with higher population density will have higher potential to turn profits and more capacity to reinvest in climate preparedness and response. Additionally, SWEs operating in high-density regions will be more capable of offering continuous service in the event of climate events like floods or storms.
- Ability to pay: SWEs operating in regions with higher average incomes will have a greater capacity to fund climate resilience by passing adaptation costs on to customers without losing significant volume.

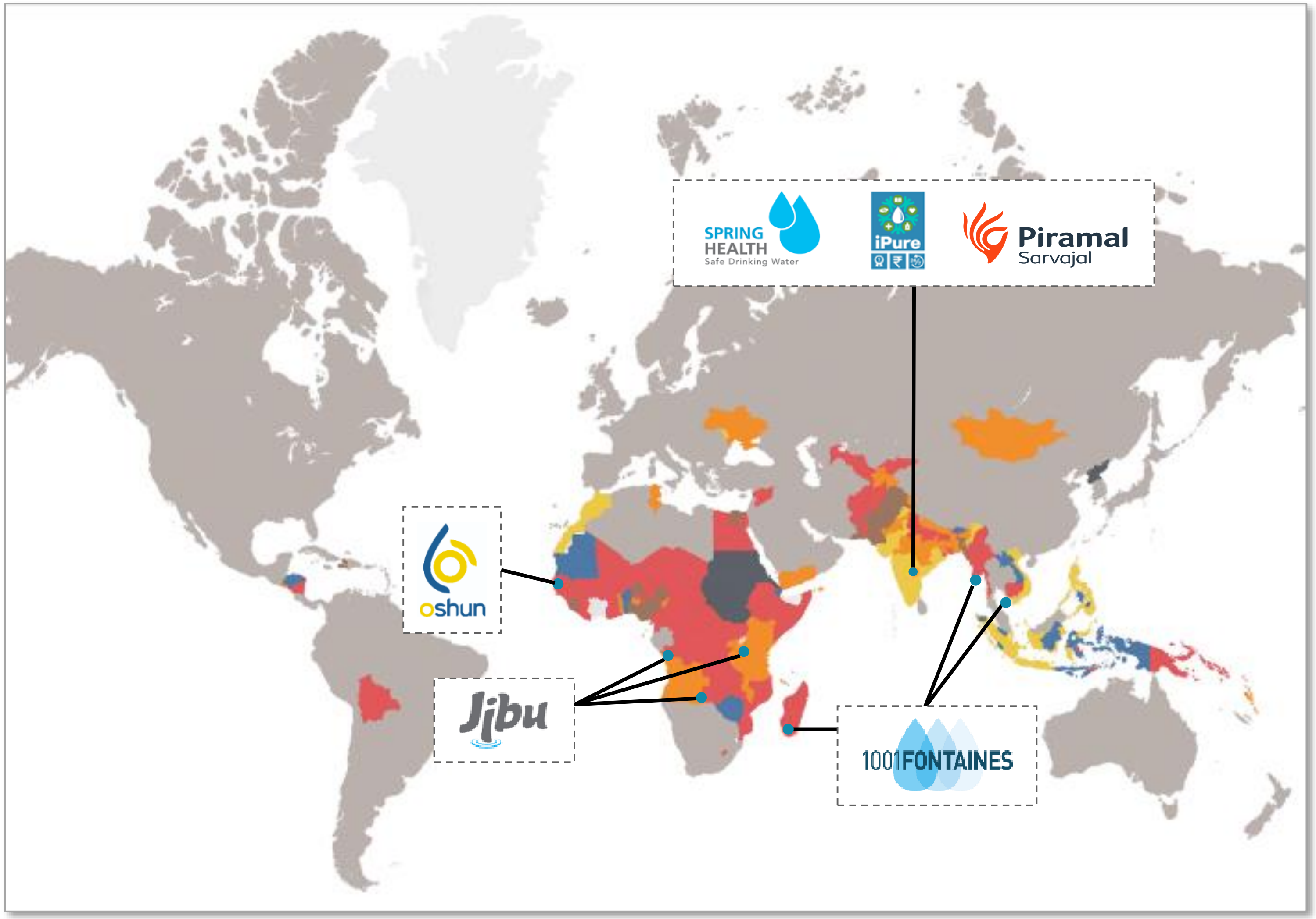
Institutional Support

Legal-institutional elements of an SWE's operating environment will contribute to SWE resilience by determining the efficiency of the local business environment and the regulatory attitude towards climate adaptation.

- Ease of Doing Business: Legal and institutional norms around efficient, transparent business practices enable climate resilience both directly, by facilitating necessary planning and construction for climate resilience, and indirectly, by enabling businesses to be more profitable.
- Sustainable Policy Environment: Government attitudes and policies towards sustainability enable SWEs to access additional resources for climate adaptation, and to implement adaptations more easily.

Source: Dalberg analysis

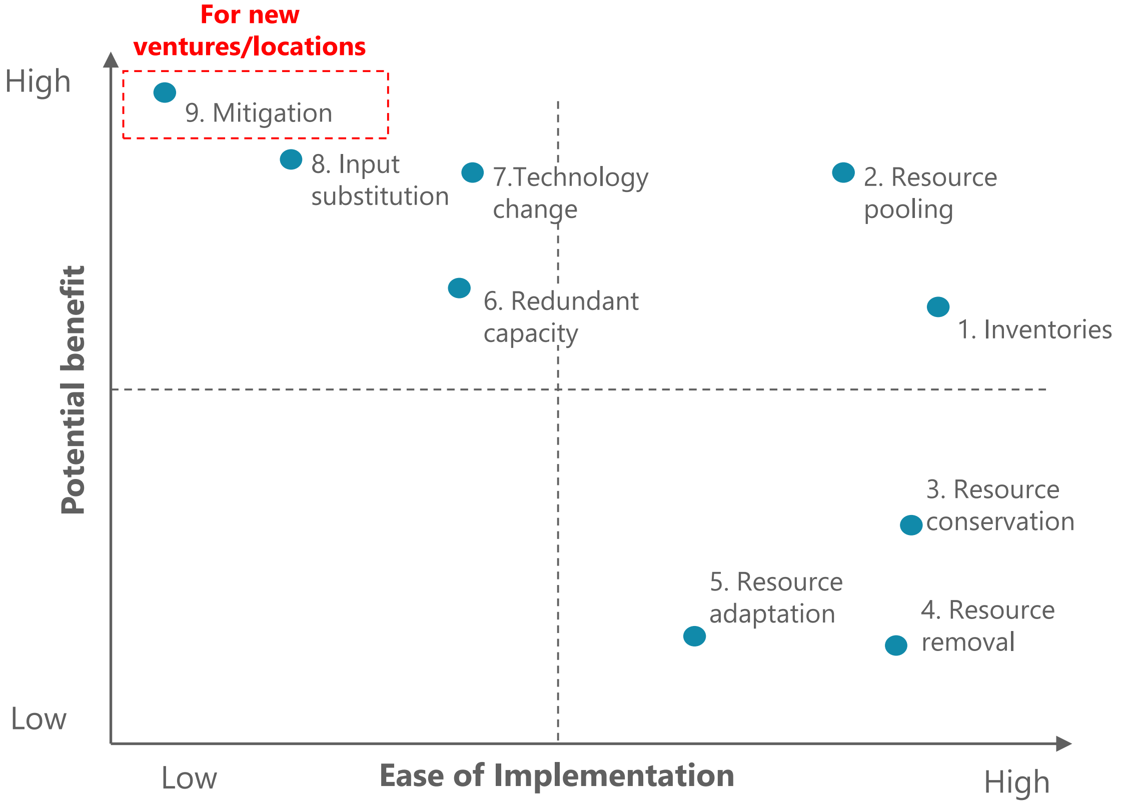
We've divided the world into 'resilience categories' based on the availability of these resilience resources



Risk category definitions	Population (in mn) and sample regions
Vulnerable: Sparsely populated regions with low income, low financing and poor institutions; limited resilience capacity	**~1100** **Cambodia, Madagascar**
Financing-led: Relatively high access to domestic/ intl. finance; resilience likely driven by financing availability	**~200** **Laos**
Demand-led: Relatively dense regions with affluent customers; resilience likely driven by robust demand	**~500** **Nigeria, Pakistan**
Moderate: Moderate access to financing, service demand and institutions; medium capacity	**~700** **Kenya, Central India**
Well-rounded: Sufficient financing, service demand and institutional structures; well placed to respond	**~1100** **South India, Vietnam**
Comprehensive: Robust financing options, demand pool, business climate and climate policies	**~3800** **Iceland**

Note: ~84M worth of population not included in the analysis due to low data availability
Source: 1. Dalberg analysis

Through SWE interviews and lessons from adjacent sectors, we have identified 9 categories of tactics that SWEs can deploy to build resilience



Legend

Ease of Implementation	Potential benefit
Low: Most SWEs cannot implement without external support	Low: Provides minimal climate resilience
Medium: Most SWEs can implement	Medium: Provides temporary or incomplete resilience to moderate climate challenges
High: All SWEs can implement	High: Provides substantial resilience to severe climate impacts

Categories of SWE Climate Adaptation Techniques

1. Inventories: Building excess inventory of both raw & treated water, and other essential supplies
2. Resource pooling: Pooling critical resources across SWE locations and with other players in the supply chain
3. Conservation: Maintaining intended water production and service levels using lower amounts of production inputs
4. Resource removal: Modifying a portion of SWE operations to run without specific process inputs
5. Resource adaptation: Modifying existing SWE resources to enable new purposes
6. Redundant capacity: Building redundant capacity of key inputs such as energy to keep the SWE running in the face of shocks
7. Technology change: Shifting critical technology/ filtration processes for SWEs
8. Input substitution: Replacing a key production input in short supply with another (e.g., replacing electricity by natural gas)
9. Mitigation-oriented design: Designing infrastructure and processes to mitigate impact of disruption on primary production processes, especially at the beginning of a new SWE venture

Source: Dormady, Roa-Henriquez, and Rose, "Economic Resilience of the Firm: A Production Theory Approach," International Journal of Production Economics July 2018; SWE interviews; Dalberg analysis

Within these 9 categories, we have further detailed a set of tactics that SWEs can deploy to build resilience (1/3)

Category	Description	SWE Tactics	Ease of Implementation	Potential Benefit	SWEs Implementing
1. Inventories	Building excess inventory of both raw & treated water, and other essential supplies	1. Water tanks to store excess capacity for shortages	High	High	Jibu, 1001 Fontaines, Spring Health, iPure
		2. Stocking excess treatment materials	High	Medium	None currently
2. Resource pooling	Pooling critical resources across SWE locations and with other players in the supply chain	3. Temporarily sending water from operating kiosks to non-operational ones	High	High	1001 Fontaines, Spring Health
3. Resource Conservation	Maintaining intended water production and service levels using lower amounts of production inputs	4. Identify minimum viable staffing and resourcing model for emergencies	High	Low	oshun
		5. Reducing raw water wastage through runoff tanks	High	Low	None currently

SWE	Situation	Response	Cost	Benefit
1001fontaines Cambodia	In 2019, a severe drought left water levels at many kiosks so low that the kiosks were not able to sustain continuous operations	1001fontaines developed a drought mitigation plan that prioritized obtaining treated or raw water from nearby kiosks that were operational	Low. Included: (1) cost of compensating donor site entrepreneur, and (2) cost of transport of raw/treated water	• Continuity: Sites remained capable of delivering service • Quantity: Maintained pre-drought quantities

Source: Dormady, Roa-Henriquez, and Rose, "Economic Resilience of the Firm: A Production Theory Approach," International Journal of Production Economics July 2018; SWE interviews; Dalberg analysis

Resilience enablers

Within these 9 categories, we have further detailed a set of tactics that SWEs can deploy to build resilience (2/3)

Category	Description	SWE Tactics	Ease of Implementation	Potential Benefit	SWEs Implementing
4. Resource removal	Modifying a portion of SWE operations to run without specific process inputs	6. Temporarily using fewer treatment resources in an emergency	High	Low	None currently
		7. Suspending delivery services in an emergency	High	Low	1001 FONTAINES
5. Resource adaptation	Modifying existing SWE resources to enable new purposes	8. Expanding delivery services in an emergency	High	Low	1001 FONTAINES
		9. Using existing monitoring technologies (e.g., battery charging reports) to monitor kiosk health in a disaster (e.g., a hurricane)	High	Low	Piramal Sarvajal
		10. Using existing mobile messaging to reach out to customers in a disaster	High	Low	Piramal Sarvajal
		11. Expanding product mix to sell additional essentials in an emergency (e.g., diversification between drinking and non-potable water)	High	Low	None currently
6. Redundant capacity	Building redundant capacity of key inputs such as energy to keep the SWE running in the face of shocks	12. Generators or batteries for backup power supply	Low	High	1001 FONTAINES, Spring Health
		13. Solar panels to mitigate against outages/energy price shocks	Low	High	Piramal Sarvajal, Spring Health
		14. Having overtime systems for emergencies	High	Medium	iPure
		15. Stock excess cans for distribution	High	Low	None currently

SWE	Situation	Response	Cost	Benefit
Piramal Sarvajal **Sarvajal** India	When Cyclone Fani struck Orissa in 2019, many Sarvajal kiosks sustained damage from the cyclone's high winds and from flooding.	Sarvajal activated existing IoT-based monitoring on essential infrastructure to understand which kiosks were online and what repairs were necessary.	None. Sarvajal had already installed these systems for regular ops; they could be adapted in an emergency.	• Continuity: Sarvajal identified 30 sites could continue ops, and prioritized repairs at remaining 6.

Source: Dormady, Roa-Henriquez, and Rose, "Economic Resilience of the Firm: A Production Theory Approach," International Journal of Production Economics July 2018; SWE interviews; Dalberg analysis

Within these 9 categories, we have further detailed a set of tactics that SWEs can deploy to build resilience (3/3)

Category	Description	SWE Tactics	Ease of Implementation	Potential Benefit	Surveyed SWEs Implementing
7. Technology change	Shifting critical technology/ filtration processes for SWEs	16. Changing treatment technologies due to shifts in water quality	Low-Medium	High	Piramal Sarvajal, Spring Health, Jibu
8. Input substitution	Replacing a key production input in short supply with another (e.g., replacing electricity with natural gas)	17. Temporarily changing water input sources in event of drought or quality degradation (e.g., tanker)	Medium	High	iPure, 1001 Fontaines, Spring Health, Jibu
		18. Change to alternate energy source (generator, battery, solar)	Low	High	Spring Health, Piramal Sarvajal
		19. Locate and install permanent backup/alternative water supply	Low	High	iPure, Piramal Sarvajal, 1001 Fontaines
9. Mitigation-oriented design	Designing infrastructure and processes to mitigate impact of disruption on primary production processes, especially at the beginning of a new SWE venture	20. Site selection studies to select climate-proof water resources and locations	Low	High	All
		21. Site infrastructure design (e.g., elevation) to prevent flood damage	Low	High	1001 Fontaines, Piramal Sarvajal, Spring Health
		22. Water resource enhancement to increase long-term groundwater recharge	Low	High	Piramal Sarvajal

SWE	Situation	Response	Cost	Benefit
Spring Health India	Ground water quality has declined over time, due partially to decreased recharge as monsoon rains have become more unreliable	Spring Health has begun to switch from chlorination-based treatment to chlorine dioxide treatment systems	Initial capex 4-5x greater for chlorine dioxide systems than for chlorination systems	• Quality: Output water is higher quality (reduced TDS) • Quantity: Increased quantity of output

Source: Dormady, Roa-Henriquez, and Rose, "Economic Resilience of the Firm: A Production Theory Approach," International Journal of Production Economics July 2018; SWE interviews; Dalberg analysis

SWEs frequently combine these tactics in similar ways to confront common climate challenges (1/2)

Scenario	Combination of Tactics Utilized	Typical Cost	Efficacy	Support Required
Scenario 1 Periodic flooding	7. Suspending delivery services in an emergency 18. Change to alternate energy source (generator, battery, solar) 20. Site selection studies to select climate-proof water resources 21. Site infrastructure design (e.g., elevation) to prevent flood damage	**Medium** Infrastructure design entails some cost to elevate equipment	**High** SWEs which implement sufficient planning tend to be highly resilient to floods	**Intrinsic** SWEs tend to have resources to manage regular floods
Scenario 2 Seasonal drying	1. Water tanks to store excess capacity for shortages 3. Temporarily sending water from operating kiosks to non-operational ones (common) 5. Reducing raw water wastage 17. Temporarily changing water input sources in event of drought or quality degradation (e.g., tanker) 20. Site selection studies to select climate-proof water resources	**Medium** Thorough site selection studies require up-front resource investment	**High** Proper planning and interoperative kiosk networks can effectively limit cost and disruption	**Intrinsic** SWEs tend to have resources to prepare for seasonal dryings in course of business ops
Scenario 3 Major drought	3. Temporarily sending water from operating kiosks to non-operational ones 5. Reducing raw water wastage 17. Temporarily changing water input sources in event of drought or quality degradation (e.g., tanker) 18. Locate and install permanent backup/alternative water supply	**High** Changing water sources and long-term tanker reliance are costly solutions	**Low-Medium** Temporary measures can alleviate immediate impact, but do not provide long-term resilience	**Financial, Institutional** To adapt to severe drought, SWEs should have policy and financial support for redundancy

Climate scenarios have been selected considering those which are most likely to impact SWEs within the time frame of this study (10 years, i.e. up to 2030); as a result, primarily shock events are represented. In the longer term (30-50 years), stress events like permanent change in water availability will also have a sizeable impact; however, these are outside the scope of the current study.

Source: 1. SWE interviews; 2. Dalberg analysis

SWEs frequently combine these tactics in similar ways to confront common climate challenges (2/2)

Scenario	Combination of Tactics Utilized	Typical Cost	Efficacy	Support Required
Scenario 4 Recurring exposure to severe storms	1. Water tanks to store excess capacity for shortages 2. Stocking excess treatment materials 4. Identify minimum viable staffing and resourcing model for emergencies 9. Using existing monitoring technologies (e.g., battery charging reports) to monitor kiosk health in a disaster (e.g., a hurricane) 10. Using existing mobile messaging to reach out to customers in a disaster 18. Change to alternate energy source (generator, battery, solar) 21. Site infrastructure design (e.g., elevation) to prevent flood damage	**High** Design and infrastructure modifications significantly increase capex **Low** For remaining tactics, only adaptation of existing methods is required	**High** SWEs that implement proper infrastructure redesigns and monitoring equipment can have effective storm resistance	**Financial** Financial support to design and implement upgraded infrastructure
Scenario 5 Declining water quality	16. Changing treatment technologies due to shifts in water quality	**Medium** Changing technology requires sizeable but manageable investment	**High** Technological changes can effectively address quality concerns	**Intrinsic** SWEs do not require outside support to adjust to quality changes

Source: 1. SWE interviews; 2. Dalberg analysis

Comparison: Spotlight on Water Mini-grids

SWEs and water mini-grids each offer distinct resilience advantages

	SWEs	Mini-Grids
Description	Safe Water Enterprises (SWEs) are localized safe water producers that typically sell treated water ***for pickup or delivery in containers*** (most often 20L cans). Water is typically ***extracted, treated, and sold from the same location***.	Like SWEs, mini-grid operators operate localized safe water provision businesses. Distinctly, mini-grid operators typically refine water at a single central location (e.g., a borewell), ***from where water is piped to satellite distribution points as well as individual homes and businesses*** throughout a village or neighborhood.
Resilience Advantages	• Continuity: SWEs simple, centralized production process enables SWEs • Affordability: SWEs require significantly less investment in infrastructure which may be exposed to climate-induced shocks	• Quantity: Mini-grids are equipped to produce and distribute services to thousands of consumers daily (significantly more than most SWE locations) • Accessibility: Delivery to local distribution points and to individual houses enables significantly greater accessibility during climate-induced shocks (e.g., storms)
Climate Exposures	• Quantity: Consumers consumption is limited by how much they can transport from the distribution location (typically in 20L cans) • Accessibility: SWEs require consumers to transport water from a central distribution point to their homes, which becomes increasingly difficult during extreme climate events	• Continuity: Higher volume, distributed piped networks are more vulnerable to disruption from extreme events (e.g., water contamination from floods) • Affordability: Piped networks require higher capex and maintenance costs, which may increase over time and be disproportionately exposed to climate events like floods and storms

Source: SWE and Mini-grid operator interviews; Dalberg analysis

Comprehensive SWE Climate Resilience Analysis

Climate water risks

An SWE's climate risk will be determined by ***aggregate local climate risk factors***, including (non-exhaustive):

- Increased frequency and severity of **extreme weather events** (storms, floods, droughts)
- Impact of **sea level rise** (flooding, groundwater salination)
- Change in **established precipitation patterns** (changing wet and dry seasons, altered precipitation quantities)

Resilience enablers

An SWE's climate resilience will be enabled by three types of ***external features of the SWE's local community:***

- Financial ecosystem (e.g., availability of finance
- Market vibrancy (e.g., demand factors)
- Institutional support (e.g., regulatory risk)

Comprehensive SWE Climate Resilience Analysis

The comprehensive climate resilience analysis considers both of these inputs to derive a meaningful understanding of SWEs' exposure to climate change

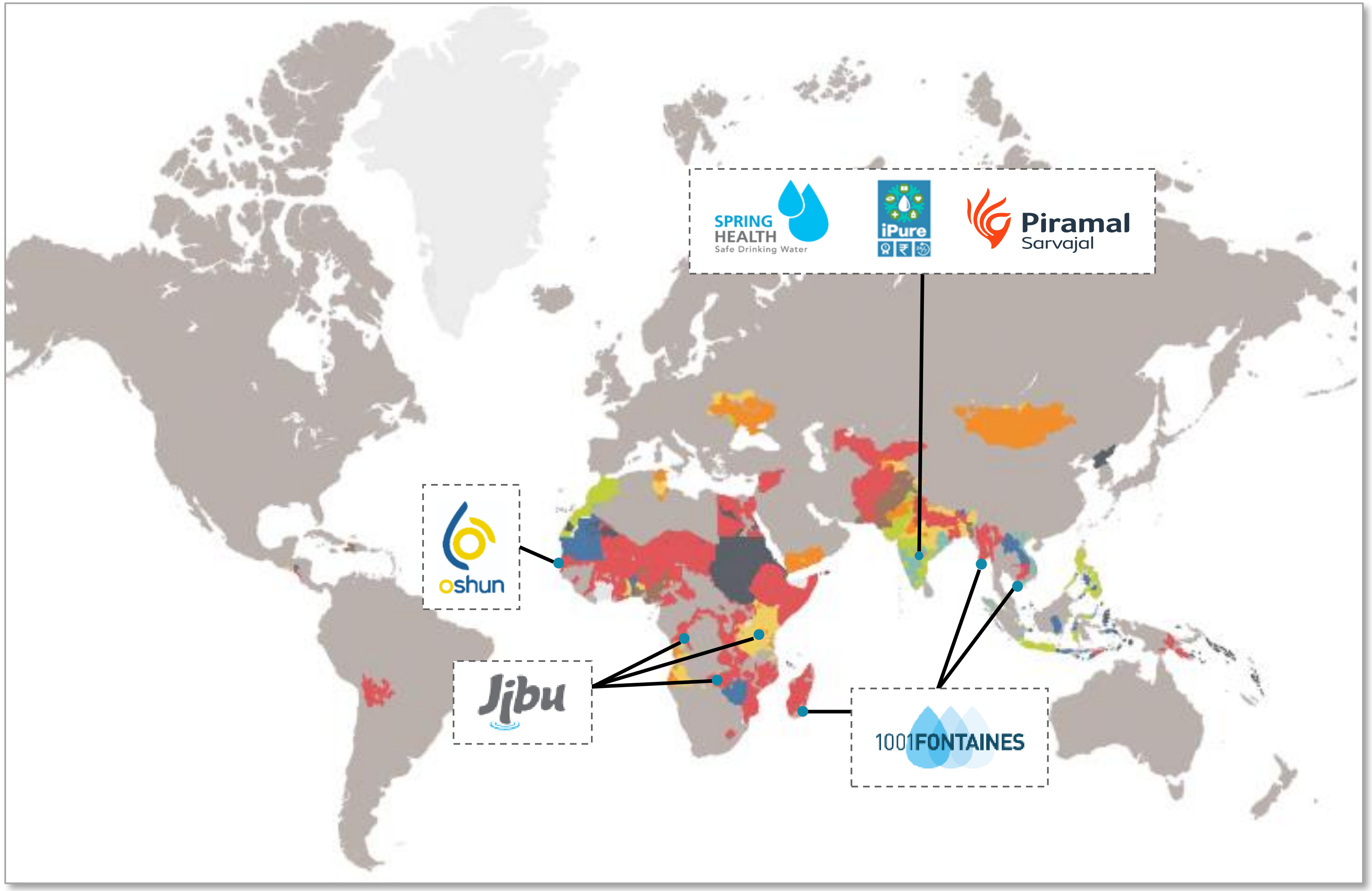
Combining risks and resilience, we have identified seven segments that are relevant to the SWE ecosystem

Focus of study[1]

Climate resilience segment	Climate Water Risk	Resilience enablers	Definition	Population (millions)	Potential customers (% of total pop.)[2]
• *Moderate/high risk,* **vulnerable**			Most vulnerable regions - medium to high risk of climate change and very little capacity for resilience	~900	83%
• *Moderate/high risk,* **financing-led resilience**			While climate risk is high, water systems in these regions are able to access domestic and/or intl. financing to build resilience. Due to low density and/or income levels, they cannot depend on strong demand when under duress	~100	68%
• *Moderate/high risk,* **demand-led resilience**			While climate risk is high and financing options and institutional support is low, these regions are dense and have high income households; this robust demand likely to be a buffer during climate stress	~400	83%
• *High risk,* **moderate resilience**			Moderate level of resources available to respond to the significant climate change impact expected	~100	77%
• *Moderate risk,* **moderate resilience**			Moderate level of resources available to respond to the medium climate change impact expected	~400	82%
• *High risk,* **well-rounded**			Despite high climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt	~400	74%
• *Moderate risk.* **well-rounded**			Despite moderate climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt	~300	75%
• *Low/very low climate risk*			Regions where water levels are high and climate change is unlikely to affect seasonal variation or water stress	~900	72%
• **Comprehensive**			Regions that are well placed to respond to any magnitude of climate change, driven by a robust social and financial ecosystem	~3800	40%

Note: 1. The final two segments (8 and 9) are at very low risk and/or have high resilience (typically in wealthy countries). We have excluded them from more detailed analysis in this study as their resilience levels are already high. 2. Total underserved segment not currently receiving water from safe sources; ~115M worth of population not included in the analysis due to low data availability
Source: Dalberg analysis

Large SWEs and funders engage across a range of 'climate resilience segments,' which have varying levels of water climate risk and resilience

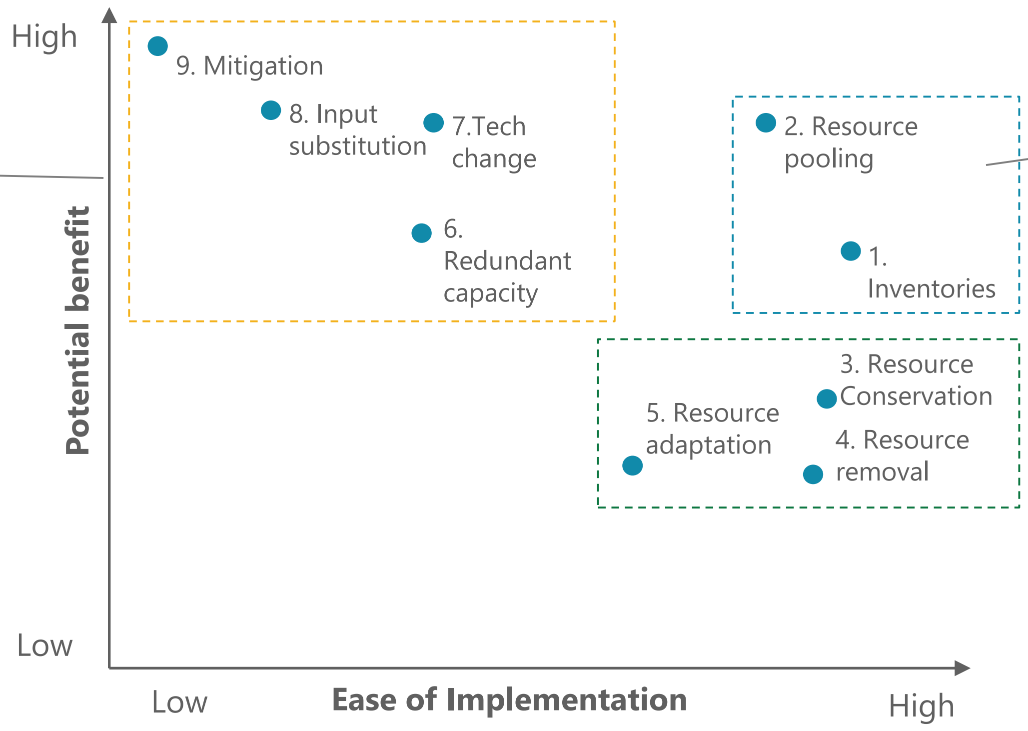


Climate resilience segments	Population (in mn) and sample regions
Moderate/high risk, **vulnerable**	**~900 Cambodia, Ghana**
Moderate/high risk, **financing-led resilience**	**~100 Bhutan, Laos**
Moderate/high risk, **demand-led resilience**	**~400 Pakistan, South Nigeria**
High risk, **moderate resilience**	**~100 Mongolia, North Tunisia**
Moderate risk, **moderate resilience**	**~400 Kenya, Rwanda,**
High risk, **well-rounded**	**400 West India, Morocco**
Moderate risk. **well-rounded**	**~300 Southwest India, Vietnam**
Low data availability	-

Note: Only included the 7 segments in focus for the analysis above; ~115M worth of population not included in the analysis due to low data availability
Source: WRI Aqueduct Global Maps 2.1 Data; Dalberg analysis

Depending on tactics needed in a segment, capex to build resilience will range from $8,000 *(quick wins only)* to $55,000 *(comprehensive)* per site

Long term plays: Investments like solar panels to generate and batteries to store energy, changing treatment technologies, and site selection studies to build resilience will require one-time per-site capex of **~$27,000 to $37,000** (PPP). Over the lifecycle of these investments, the **cost per 1,000L will increase by ~$4.20 to $4.75.**



Quick wins: Purchasing water tanks to store excess capacity and arranging for transport across sites will involve a one-time per-site capex of **~$8,000** (PPP). Over the lifecycle of these investments, the **cost per 1,000L will increase by ~$0.88**

Incremental gains: Adapting existing mobile messaging systems to reach customers during a shock event, reducing wastage through runoff tanks, and expanding product mix require capex of **~$7,600** (PPP). Over the lifecycle of these investments, the **cost per 1,000L will increase by ~$1.39**

In addition to investments requiring capex, there will be opex impact across the value chain that will range from $1.14 per 1,000L in low climate risk regions to $3.73 in high risk areas

Note: Calculations assume an average of 10 sites per scale investment. Each investment has an assigned lifecycle, which is why capex is not directly proportional to implications on cost per 1,000L.The range for Long Term Plays is based on investing in solar panels and backup (higher cost) vs. generators and batteries (lower cost).

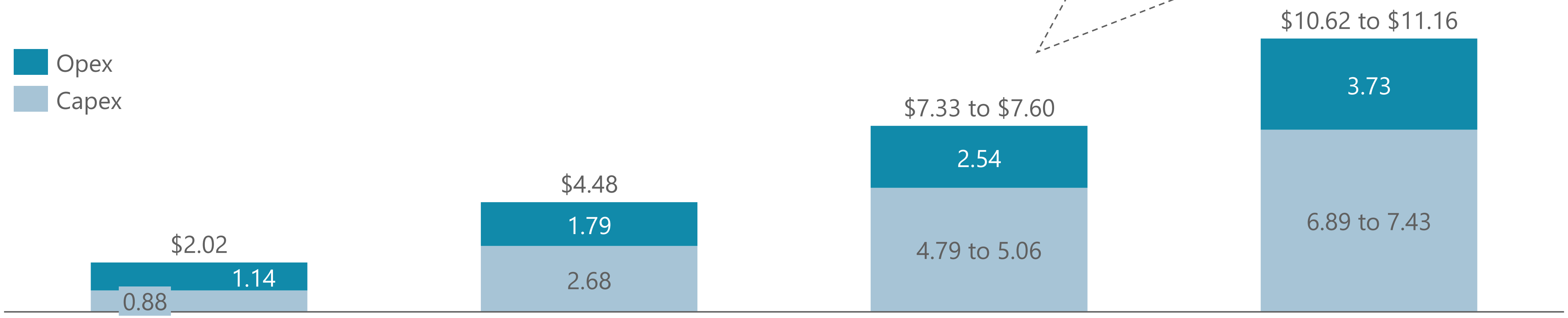
SWE Assessment

Adding capex and opex, total cost to serve will likely rise by ~3% in low risk areas and as much as ~18% in regions with highest climate risk

Increase in cost per 1000L by 2030

USD PPP per 1000L

The actual nature of adaptation tactics employed will vary across segments depending on the magnitude of the regional climate challenge and local resources

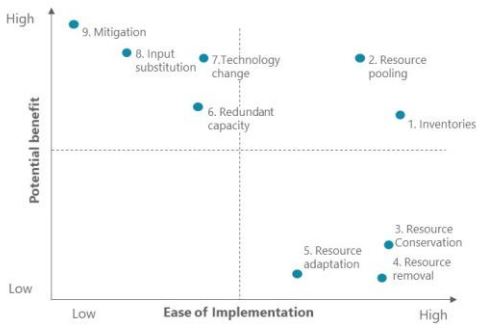


Climate Water Risk Level	Low	Low - medium	Medium - high	High
% of cost to serve	3.3%	7.2%	11.7 to 12.3%	17.1% to 18.0%
Typical approach	• Identify ***low-cost, 'quick win' prep*** scenarios to address minor climate impacts • SWE resources should be sufficient for implementation at all SWEs	• Survey SWE locations to ***identify any particularly at-risk locations***; focus mitigation in these areas • SWE resources should be sufficient for implementation at most SWEs	• Prepare climate ***response steps for sizeable events impacting a majority of sites*** • Pursue site upgrades • Most SWEs will require some external support	• Invest in ***comprehensive mitigation*** to major impact at all sites • Leverage significant resources (internal or external) to fund necessary mitigation methods

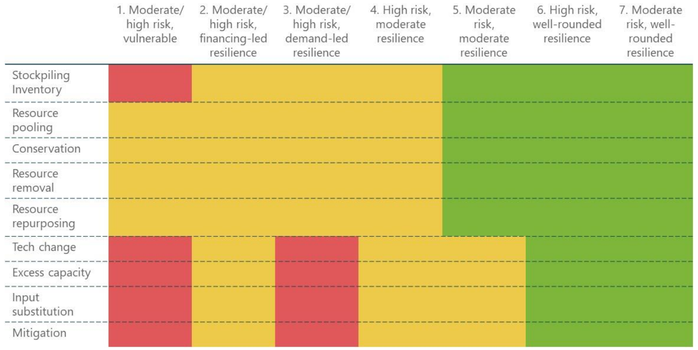
We have assigned a resilience score for each segment, and combining that with the water risk score provides a segment summary

The resilience score assigns each segment a score based on expected impact and ability to respond (intrinsically or with assistance)

To develop a resilience score, each resilience category was assigned a weight based on expected benefits. The highest impact resilience categories received the highest weightage.



Segment scores were developed based on their ability to adopt resilience tactics. Segments that can intrinsically adopt all tactics received a perfect score. Assisted resilience received half the credit, while inability to deploy a tactic received zero points.



Combining the above steps, each segment received a resilience score out of 4

Combining the resilience score with the water risk score above, we can identify which segments are secure and which are at risk

Segment	*Water risk score*	*Resilience score*	*Segment summary*[1]
1. Moderate/ high risk, vulnerable	3.2 – 3.8	0.57	15 – 18
2. Moderate/ high risk, financing-led	3.2 – 3.8	2.00	53-63
3. Moderate/ high risk, demand-led	3.2 – 3.8	0.79	21 – 25
4. High risk, moderate	3.8	2.00	53
5. Moderate risk, moderate	2.0 – 3.2	2.79	87 – 140
6. High risk, well-rounded	3.8	4.00	105
7. Moderate risk, well-rounded	3.2	4.00	125

Segment summary	*Interpretation*
0 to 50	Will struggle to build resilience against climate change
50 to 100	Largely assisted resilience with some gaps
100+	Strong resilience with minimal need for assistance

1. The Segment Summary score is calculated by dividing the resilience score by the water risk score. Where resilience is higher than risk, the segment is considered secure.

In summary, Segments 1 and 3 are likely to require significant assistance to respond to climate change; 5, 6, and 7 can more easily build resilience

		Segment 1: *Moderate/high risk*, **vulnerable**	*Segment 2:* *Moderate/high risk*, **financing-led resilience**	*Segment 3:* *Moderate/high risk*, **demand-led resilience**	*Segment 4:* *High risk*, **moderate resilience**	*Segment 5:* *Moderate risk*, **moderate resilience**	*Segment 6:* *High risk*, **well-rounded**	*Segment 7:* *Moderate risk*, **well-rounded**
Key assessment parameters	**Total population**	900M	100M	400M	100M	400M	400M	300M
	Market size	720M	40M	330M	110M	350M	330M	240M
	Water risk score	3.2-3.8	3.2-3.8	3.2-3.8	3.8	2.0-3.2	3.8	2.0-3.2
	Resilience score	0.57	2.00	0.79	2.00	2.79	4.00	4.00
	Segment summary	15 – 18	53-63	21-25	53	87-140	105	125
	Cost of adaptation (USD PPP per 1000L)	7.33 to 11.16	7.33 to 11.16	7.33 to 11.16	10.62 to 11.16	4.48 to 7.60	10.62 to 11.16	4.48 to 7.60

Government or philanthropic funding may be required to address the resilience gap in segments 1 and 3, which contain very large numbers of unserved people

Note: 1. Intrinsic and assisted resilience calculated based on the fraction of resilience tactics SWEs in a segment would be able to execute independently and with external assistance, respectively (see slide 43); tactics with higher potential benefit have been given a higher weightage; similarly, tactics able to be executed through intrinsic resilience have been given a higher weightage than the ones through assisted resilience
Source: Dalberg analysis

Table of Contents

SWEs are a resilient channel to deliver safe drinking water in the face of climate change; but will require targeted support to succeed at scale

Different stakeholders can use this report to explore ways to advance their strategic and social objectives, with an eye to both safe water access and climate resilience. In particular, stakeholders can seek to:

SWEs

- Assess the key water climate risks to their operations
- Adopt climate resilient business practices to respond to their risk scenario and in response to local context
- Leverage climate knowledge to activate new sources of investment.

Funders

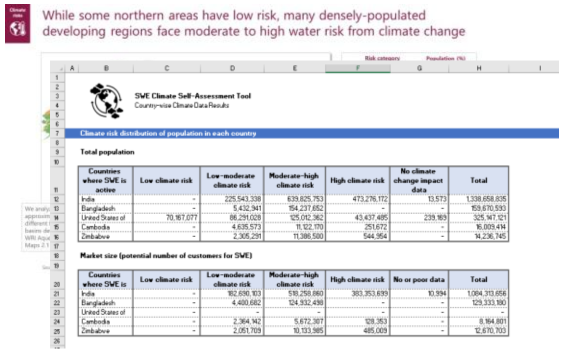
- Make targeted investments in existing portfolio to build climate resilience
- Plan future investments to maximize impact through climate-aware assessment
- Build support for the SWE ecosystem through an improved understanding of the climate x water nexus

Policymakers

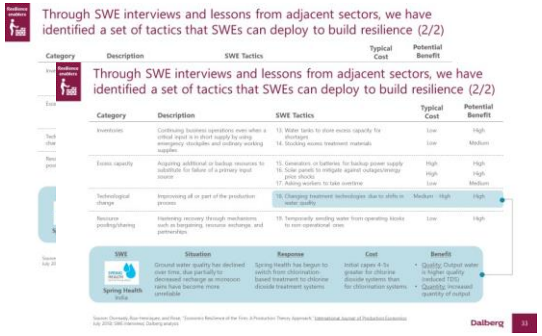
- Adapt resilience framework to assess climate resilience of water systems
- Deploy subsidies, grants, or loans to support SWEs in regions where government intervention is needed to build resilience against water climate risk

Tools presented along with this report can be used to further contextualize the analysis

Spreadsheet to understand geography-specific water climate risk and resilience



Complete set of climate-resilient tactics that SWEs can adopt, investors can fund, and policymakers can incentivize (pgs. 41 to 44 of this report)



Funders: Adopt a targeted approach to SWEs due to climate risk; hybrid financing & common resilience blueprints will be key

The findings in this report suggest a set of six key implications for funders in the SWE ecosystem spanning the investment lifecycle. These recommendations will be useful to both current funders already engaged with SWEs, and for funders looking to expand into the sector. This includes traditional investors, impact-oriented investors, and mission-driven philanthropic funders.

Investment lifecycle

Fundraising

1 **Importance of hybrid finance**: Climate change will increase the cost of SWE operations in many regions, driven in large part by changes in the cost of treatment. These effects will be particularly pronounced in areas with high climate water risk. Ensuring continued operations in the face of climate stresses and shocks will require investment to mitigate expected business impacts. In order to ensure that water remains affordable to low income segments, funders should help to subsidize these costs through hybrid finance instruments.

Ecosystem Building

2 **Advocacy and Knowledge Sharing:** Advocate the comparative advantage of SWEs in the face of climate change in order to help crowd in additional support from investors, international organizations, and local governments.

3 **Coalition Building**: SWEs should help partner with impact-oriented funders to spearhead the creation of a coalition of climate- water financing funders to ensure that robust financing, including hybrid models, remain available.

Investing

4 **Targeted investment**: Climate change risk and segment economics will vary across segments. Investors and funders should consider this reality as part of their investment planning processes in order to identify segments where they want to engage (see next slide for a mapping).

Portfolio Company Optimization

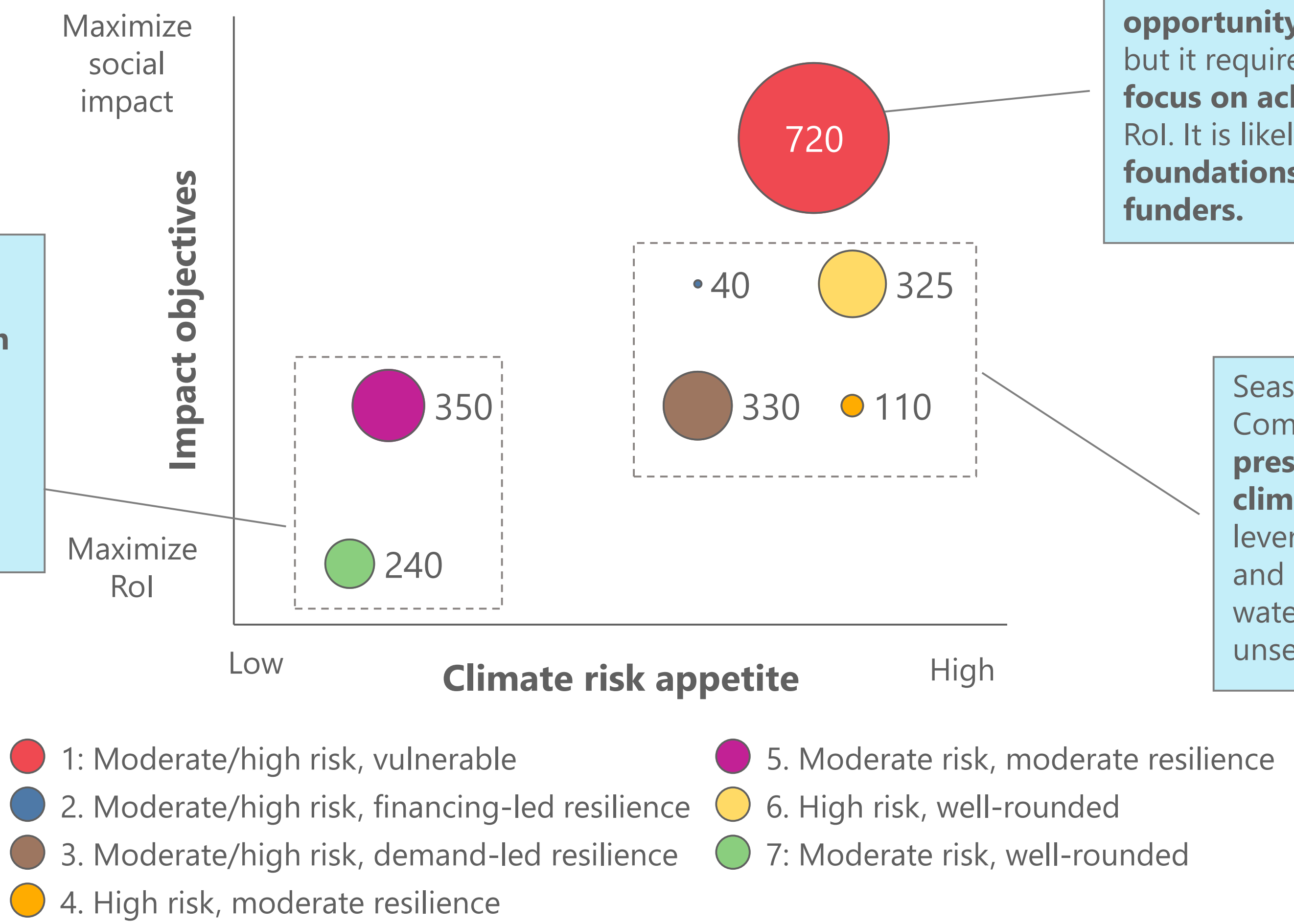
5 **Climate Blueprints:** Create blueprints for climate resilient service delivery and infrastructure that can be shared with and implemented by all investees. Ensure that existing projects upgrade their operations to incorporate climate resilience best practices, and that new projects comply with these standards from project inception.

6 **Climate Insurance**: Invest in group climate-linked insurance products to provide a financial backstop to support projects experiencing severe, idiosyncratic climate shocks.

Investors: Investors can target their investments in the SWE ecosystem based on their objectives and risk appetite

The seven segments represent a range of investment options in terms of risk as well as potential social impact, with varying implications for different types of investors. The size of bubble represents number of unserved people in segment; image excludes regions with low climate risk or missing data.

The segments with lowest risk still constitute a large opportunity of **590 million people**. These are best suited for **low-risk investors or prospective funders looking to enter the SWE market**.



The vulnerable segment represents the **largest opportunity** with 720 million unserved people, but it requires significant risk appetite and a **focus on achieving social impact** rather than RoI. It is likely best served by **governments, foundations, and other non-return seeking funders.**

Seasoned SWE investors like Danone Communities should look to **expand their presence in segments with moderate to high climate risk,** where their experience can be leveraged to help SWEs build climate resilience and ensure continuous supply of safe drinking water. These segments contain **805 million** unserved people.

SWEs: Climate change will increase treatment costs; affordability and quality will see sizeable impacts, while quantity will be less affected

Key effects of climate change on SWEs

Over the next decade, **shock events are more likely than stress events to disrupt SWE water provision**. These will largely impact **water quality** (e.g. contamination of sources due to flooding), which in turn affect **affordability** (because treatment costs rise). Other safe water parameters – continuity, quantity, and accessibility – will be less affected.

In regions with the highest climate water risk, treatment costs will increase by 32% and to bring back service levels and costs to BAU will require an **adaptation** opex that **will range from $1.14 to $3.73 per 1,000L based on segment**. Depending on the adaptations necessary to achieve climate resilience, capex will additionally range from $0.88 to $7.43 per 1000L. This will represent between 3% and 18% of the price of water, with nearly 90% of the opex increase driven by treatment costs.

The results of this study also carry several implications for SWE's engagements with governments, funders, and users, as well as their planning for their own infrastructure requirements and expenditures.

Engagement with Governments

- In highly vulnerable regions like Cambodia, Madagascar, and Afghanistan, SWEs should proactively seek to build relationships with **governments or foundations for subsidies or grants** to fund essential climate resilience preparations. Specifically, support that **reduces treatment costs** could be especially impactful

Engagement with Funders

- In well-rounded regions, SWEs can mix their own resources with return-seeking market finance
- By comparison, in regions like Laos and Tanzania, with financing led resilience, SWEs will need to seek external sources of financing **willing to take sub-market returns** in order to generate impact

Engagement with Users

- In regions like Pakistan and southern Nigeria, SWEs can **rely on robust demand to pass on price increases** to customers
- As water quality declines, **demand for SWE supplied water may increase** as customers look to SWEs to meet needs beyond safe drinking water (e.g. water for cooking)

SWE Infrastructure

- For short-term shocks, **simple low-cost adaptations** to existing practices can be quite effective
- For regions prone to more long term events (e.g., recurring droughts, declining water tables), **mitigation-focused planning** will be essential

Policy-
makers

Policymakers: Greater knowledge of climate risks and impacts can help assess where SWEs offer the most promising benefits

The findings in this report suggest a set of four key implications for policymakers as they look to ensure their respective population has access to safe drinking water in alignment with WHO's safe water parameters. These implications span the policymaking lifecycle – from understanding the problem, to designing a solution, and finally delivering in a risk-minimizing and impact-maximizing way.

Governance lifecycle

Diagnose

1. **Understand the vulnerability of water systems to climate change**: Policymakers can use this report to develop an improved understanding of what kind of climate risk their jurisdiction is facing and what the impact on water systems may be. They should look to holistically assess the climate risk to water in their country – including adapting the general resilience framework for piped systems – and then determine what kind of water provision (centralized vs. decentralized) is likely to work best in each region.

Plan and Design

2. **Design a comprehensive climate-resilient water supply network:** Based on region-specific understanding of water needs, supply options, and climate risk, a national level climate-resilient water delivery plan should be developed. This will likely largely depend on piped systems, but SWEs will be best-suited in certain regions (e.g. where piped delivery infrastructure is hard to build).

3. **De-risk SWEs through targeted interventions**: In regions where SWEs are identified as the optimal water solution, governments should understand what support they need to make their model viable. In the most vulnerable segments, some subsidy or viability gap funding will likely be required. In other areas, climate insurance may be the most efficient solution.

Deliver

4. **Deliver water through SWEs during climate shocks**: In regions where there is a strong case for SWEs to be part of national water delivery, governments should ensure SWEs are integrated with their systems. This is likely to be especially helpful during climate shocks, when SWEs tend to be more resilient than other improved, non-piped water systems (e.g. when flooding causes contamination, SWEs with flood-proof infrastructure can continue operation). During such events, governments should look to partner with SWEs to ensure water needs are being met.

In addition to stakeholder-specific implications, we believe our research also suggests an opportunity for bigger initiatives to be impactful

Based on our research and the findings outlined above, we also believe the following 5 "big ideas" present an opportunity to leverage networks among SWE ecosystem stakeholders to further prepare SWEs for climate change's looming impacts:

SWE Climate Alliance

A central secretariat to enable collaboration among and advocacy by SWEs for climate-oriented purposes. The SWE climate alliance should look to crowd-in resources for building climate resilience, serve as a central coordinating body for the sector (including to host the other programs proposed here), and present a unified voice to policymakers for more effective climate advocacy.

Treatment Costs Reduction Program

Program to enable (1) SWE investment in cost-efficient treatment, and (2) research into cost-effective treatment methods. Given that the largest share of SWE costs due to climate change is likely treatment-related, this program will allow SWEs to directly focus on emerging solutions to be rapidly shared and deployed.

SWE Resilience Innovation Platform

A platform to provide space and funding for climate-proofing innovations, and to act as a knowledge hub for adaptation. The platform should look to connect SWEs with innovators and adapt technologies from adjacent sectors where relevant. Funders can also play a key role in broadening the reach of the platform and connecting SWEs with potential resources.

Hybrid Financing Network

Network of investors and funders dedicated to providing flexible, impact-oriented funding for SWE climate resilience. The Network will serve as a "clearing house" where potential funders and SWEs come together. This will significantly reduce funding search costs for all actors and allow for easier and swifter funding decisions.

SWE Climate Capacity Resource Fund

A donor-driven fund to provide resources to SWEs for climate adaptations, particularly in low-resource, high-need regions. The Fund should contain two categories for deploying resources – one focused on proactively building resilience capacity and the other on providing emergency funding in extreme scenarios.

Table of Contents

Summary: Each of the following three case studies focuses on a different climate challenge and the resilience tactics SWEs used to respond

1

1001fontaines

- Location: Cambodia
- Climate challenge: Failure of the rainy season in 2019 led to severe nationwide droughts
- Response: Proactive climate planning and quick action to partner with entrepreneurs to identify alternative water resources enabled 1001fontaines to continue to supply services throughout the drought

2

Jibu

- Location: Kenya, Rwanda, Uganda, Tanzania, Zambia, Burundi, and DRC
- Climate challenge: Adaptation across multiple climate regions with different resources and regulatory regimes
- Response: Decentralized decision-making to local entrepreneurs supported by centralized expertise and resources

3

Naandi Community Water Services

- Location: Maharashtra, India
- Climate challenge: Extreme monsoon rains in 2019 led to flooding in many villages
- Response: Flood-conscious site selection enabled continuous business operations throughout the floods

4

Water4

- Location: Organization-wide (multiple sub-Saharan Africa)
- Climate Challenge: Unlike other SWEs, Water4 operates localized piped water networks for up to 3000 consumers in rural villages. Climate change presents unique challenges and opportunities to adapt.

Case study: 1001fontaines provides safe drinking water to nearly 700,000 customers in underserved rural areas of Cambodia

1001FONTAINES

Company Information

Founded: 2004

Case Study Location: Cambodia

Water Filtration Method: UV, MSSF, Carbon

Climate Segment 1: Moderate/high risk, vulnerable

3 "platforms"[1] in Battambang, Phnom Penh, and Kampong Cham support countrywide ops

~230 sites

~700,000 customers regularly in Cambodia

1800 riels / 20L

Business Model

- Organizational model: 1001fontaines funds setup, while daily operations are undertaken by an entrepreneur who lives in the local village. Operations are supported by 3 regional technical support "platforms."[1]
- Geographical focus: 1001fontaines targets customers in rural areas who are typically excluded from other safe water projects
- Customer segments: At 1800 rials/20L, water is priced at such a level that 75% of rural village consumers (including BPL consumers) can afford to purchase water while spending <3% monthly income.

Climate Risks

- Seasonal flooding resulting from increasingly forceful rains during the rainy seasons
- Increasingly severe seasonal droughts due to unreliable annual rainy seasons

Resilience Enablers

- Vulnerable: There are limited external resources in Cambodia that can bolster an SWE's intrinsic resilience

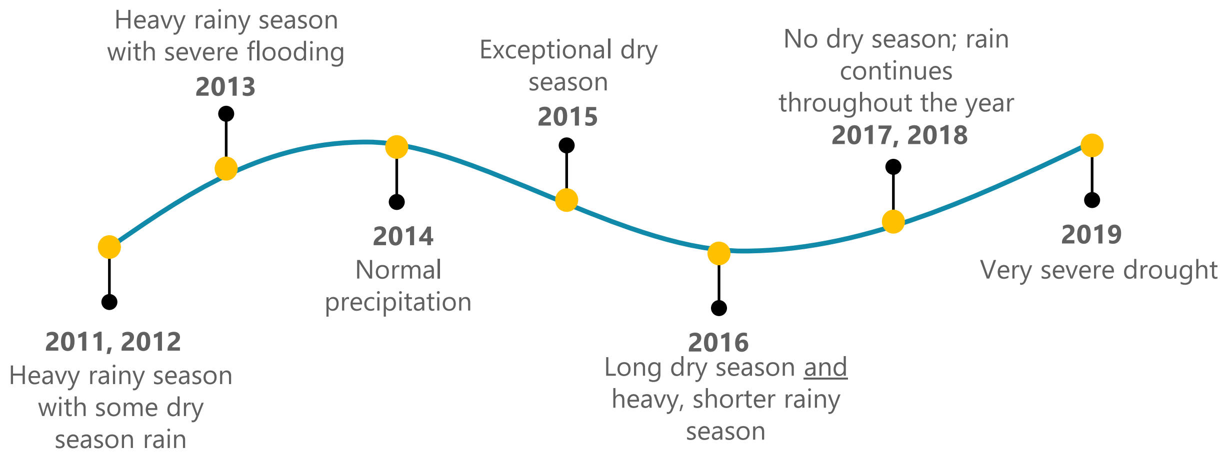
Note: 1. A platform is a technical assistance body operated by Teuk Saat 1001 (1001fontaines local partner) to support entrepreneurs with supplies and TA.

Case study: Years of increasingly inconsistent rainfall culminated in 2019 with a severe drought that left many water sources depleted

Situation Overview

- Climatically, the year in Cambodia is split between two primary seasons: a dry season (mid-November to mid-May) and a rainy season (mid-May to mid-November).
- In a regular year, water consumption at kiosks tends to be significantly *higher* during the dry season, as household rainwater harvesting is widespread during the rainy months.
- However, in recent years, traditional rainfall patterns have become more unreliable (see timeline, below)
- In 2019, the rainy season failed to arrive until August, at which point water levels had fallen so severely that water levels in the Mekong fell to a 100-year low. Many of 1001fontaines primary water sources were severely depleted.[1,2]

Timeline of Seasonal Weather Patterns in Cambodia[2]



Threats to Safe Water Supply

Drought has several potentially serious impacts on safe water supply:

Quantity	If sufficient water cannot be extracted on a daily basis, total quantity of water supplied to consumers will decline
Continuity	Drought conditions can result in temporary supply disruptions if the primary water source becomes unavailable until alternatives are identified
Quality	Surviving water sources during drought periods may have significantly higher chemical and biological contamination levels
Affordability	Changes in water source or supply method due to drought may increase production costs, which can drive down affordability
Accessibility	If a particular source is out of water, consumers may need to travel further to find a substitute

Source: 1. Mekong River Commission for Sustainable Development; 2. SWE-provided data on local rainfall conditions at 1001fontaines sites

Case study: 1001fontaines' proactive planning and institutional support channels helped 88% of sites remain open throughout the drought

Inherent Resilience Mechanisms

Financial

- Increased Demand: As alternate sources dried up, customer demand increased significantly, providing additional financial resources
- International support: 1001fontaines could provide emergency funding to local affiliates in extreme emergency

Operational

- Climate-sensitive site selection: During site selection, water resource assessments are conducted to locate a reliable source
- Drought action plan: Staff had pre-emptively developed a drought action plan, which could be deployed as conditions deteriorated

Adaptive Resilience Mechanisms

Financial

- Cash flow assistance: If entrepreneurs experience cash flow difficulties due to the drought, 1001fontaines could issue the entrepreneur debt
- External assistance: 1001fontaines has requested grant aid to improve resilience to future droughts

Operational

- Neighboring kiosks: For kiosks that ran dry, the first line of defense was to source raw or filtered water from neighboring kiosks in 1001fontaines network
- Water tankers: If kiosks were unavailable, entrepreneurs could try to hire water tankers
- Change water source: If no short-term alternatives were available, 1001fontaines would assist entrepreneur to change water sources, if possible

Outcomes

- Temporary sales spike for drinking water: On average, during the drought, sales increased by 15% per site over previous year same month sales as customers increased consumption of drinking water from 1001fontaines as alternative water sources dried up.
- Strengthened government partnerships: Because of their efforts in coping with and providing service during the drought, government agencies and international aid organizations have partnered with 1001fontaines to fund additional resilience infrastructure (e.g., water storage tanks) to guarantee rural last mile water distribution
- Increased resilience at vulnerable sites: For three of the most vulnerable water sites, 1001fontaines assisted the local entrepreneur to identify and utilize a new, permanent water source with greater capacity to resist drying during drought periods.

Key Water Outcomes

Quantity: Average per site sales increased 15% over previous year

Continuity: 88% of sites provided continuous water for the entire drought

Quality: No change in output water quality

Affordability: No change in price per liter charged to consumers

Accessibility: 12% of customers used alternate sources for 1-2 months

Source: SWE interviews; SWE data; Dalberg analysis

Case study: Lessons for other SWEs

1 The value of climate-sensitive planning

Staff proactively crafted climate-sensitive criteria into their planning from the start

- Informed by their experience dealing with years of inconsistent rains, 1001fontaines evaluates the drought-resilience of potential water sources when searching for new kiosk sites, selecting only sites with sufficiently resilient resources.
- As it began to appear that the 2019 drought would be significantly more severe than past years, 1001fontaines central staff acted quickly to draft a company-wide plan for drought mitigation measures.
- 1001fontaines regional staff communicated this plan to entrepreneurs in order to ensure that local operators were prepared with multiple mitigation options as the drought worsened.

> "It is important to prepare a clear mitigation plan for likely climate scenarios with different mitigation options and their costs, both to facilitate on-the-ground decision making by relevant teams, and to be able to share a budget request with potential donors."
>
> --Amandine Muret, 1001fontaines

2 Build partnerships through crises

100fontaines built relationships with government, community members, and NGOs as a reliable provider

- By providing continuous services through a historically-severe drought cycle, 1001fontaines built a brand in local communities as a reliable provider
- Government institutions and NGOs are now working *more* in partnership with 1001fontaines to anticipate future droughts and ensure last mile distribution to work

3 External solutions to limited finance

1001fontaines leveraged international resources to compensate for limited domestic finance resources

- Our analysis places Cambodia in Segment 1, meaning there are limited resources available domestically to finance climate resilience
- However, 1001fontaines has been able to finance both its response to severe drought and future resilience improvements by supplementing domestic financial resources through partnerships with international funders and organizations

Source: SWE interviews; SWE data; Dalberg analysis

Case study: Jibu currently serves customers in 7 countries through 110 franchise operated by local entrepreneurs

Company Information

Founded: 2012

Case Study Location: Organization-wide (multiple countries)

Water Filtration Method: Primarily UF

Climate Segment: Multiple

Operational in Kenya, Rwanda, Uganda, Tanzania, Zambia, Burundi, and DRC

~2000 operational retail sites

~500,000 customers regularly

~$1 / 20L

Business Model

- Organizational model: Jibu provides "turnkey" water treatment solutions to local franchisees (including filtration equipment, financing, and training) in return for certain startup fees and revenue sharing
- Geographical focus: Jibu's business is primarily focused in urban areas with high population density
- Customer segments: Francisees largely serve the "middle 70%" of consumers in target countries

Investment capital

Capex for treatment tech, store setup
Ongoing training, marketing
Low-cost asset financing
Maintenance and quality control

Jibu Funders

Jibu Corporate

Franchisees

Distributions
Interest

Licensing fee (one-time)
Revenue sharing
Inventory purchases
Interest

Case study: Because it operates across 7 countries, Jibu must confront a wide variety of climate risks and resilience resources

Situation Overview

Across the 7 countries in which it operates, Jibu faces a wide range of climate risks dictated by local climates, raw water extraction methods, and conditions, including:

- Floods changing water quality in some rural sites using boreholes
- Inconsistent water supply in certain urban environments using municipal water
- Persistent flooding at a site in Rwanda

Similarly, Jibu operates in a variety of regulatory and social environments across countries as well as urban and rural customer segments, including:

- In urban areas of the DRC, high need and density drives consumer-led resilience
- Zambia has significantly lower population density and urban density than the DRC, lending to increased vulnerability

Given a service model that delivers solutions across a variety of risk and resilience regions, Jibu's systems and businesses face a pressing need to adapt to a variety of climate circumstances that will continue to multiply as Jibu continues its expansion into new markets.

Climate Risks

Legend
- Low risk
- Moderate risk
- High risk

Resilience Enablers

Legend
- Moderate
- Vulnerable

Source: SWE interviews, Dalberg analysis

Case study: Jibu's centrally-supported franchise model enables operators to adapt Jibu's business model to mitigate local climate conditions

Inherent Resilience Mechanisms

Financial

- Centralized Insurance: Jibu Corporate provides insurance for core assets such as treatment systems, tanks, and pumps

Operational

- Locally-driven decision making: Entrepreneurs can respond to climate-driven business threats based on intimate knowledge of local problems and solutions
- Centralized site planning: Jibu Corporate helps survey and select appropriate sites to locate new franchises
- Excess capacity: Decentralized system contains excess capacity to cover neighboring units temporarily

Adaptive Resilience Mechanisms

Financial

- Access to Centralized Finance: Jibu Corporate provides entrepreneurs with access low-cost debt financing
- Local Financing: Entrepreneurs also raise market financing on their own to fund improvements

Operational

- Relocation Assistance: When a branch needed to relocate due to persistent flooding, Jibu Corporate provided technical and financial assistance for the shift

Outcomes

- Strong Foundations: Because entrepreneurs receive significant support onsite planning and assessment from Jibu Corporate from the start of the relationship, sites are located in locations with high resilience to floods and droughts
- Ease of Adaptability: Entrepreneurs can adapt to emerging local threats by using both locally-available finance and resources and centrally-linked opportunities
- Franchise-driven continuity: Neighboring franchises help ensure continuous supply is available even in the event of an emergency that takes some sites offline

Solution Spotlight

Franchises across regions **face water shortages** for a variety of reasons (temporary drying in borewells, lack of pressure from municipal utilities, and temporary water quality changes are the most common), local entrepreneurs have employed a variety of potential response according to circumstance:

- Utilize spare capacity in on-site storage tanks
- Borrow inventory from nearby franchises
- Negotiate with water utilities to increase or restore supply
- Pay for temporary service from water tankers

Case study: Lessons for other SWEs

1 De-centralized adaptation

Jibu franchisees can leverage local expertise to respond to local problems

- Jibu's franchisees are drawn from the local community and operate business in their local area
- Jibu franchisees, as local business operators, can use the specialized knowledge of local conditions developed operating their business to proactively identify looming climate risks
- Once risks are identified, franchisees can also leverage networks and connections to respond to challenges

2 Networked continuity

High-density networks in urban areas help ensure continuity in the event of disruption

- Jibu's urban operational model often has individual franchises or microfranchises operating in close proximity, serving areas 1-2 square kilometers in area
- By building a local network of franchises, allied franchisees serve as redundancy in the event individual suppliers experience temporary failures (e.g., from flooding) due to climate change

3 Multiple finance mechanisms

Jibu franchisees have multiple options to finance climate adaptations

- Jibu franchisees often operate in environments where local finance for capital expenditure may be difficult to raise, despite a proven business model
- Having access to both local financial resources (through community investors) and international resources (through Jibu's investment) helps enable Jibu entrepreneurs to respond to business needs, including climate-related risks

Case study: Naandi serves 750,000 customers in 7 states in India

Company Information

Founded: 2005

Case Study Location: Maharashtra, India

Water Filtration Method: RO & UV

Climate Segment 7: High risk, well rounded resources

Operational in 7 states in India, including Maharashtra

~647 kiosks operational (including directly operated and community run)

~754,000 customers regularly

~.06 USD / 20L[1]

Business Model

- Geographical focus serves a mix of kiosks in rural and urban areas
- In rural areas, locations and water sources are selected in consultation with local community leaders
- After 7 years, Naandi transfers rural sites to community operation/ownership

Climate Risks

- Seasonal flooding resulting from increasingly forceful rains during monsoons
- Seasonal drying due to depleted groundwater supplies and erratic rains

Resilience Enablers

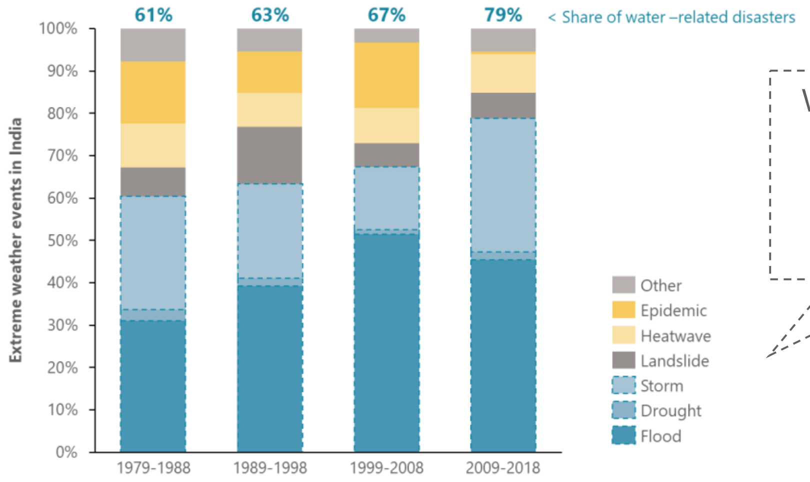
- Access to Finance: SWEs operating in India have relatively numerous avenues for attractive finance, including through domestic financial markets, corporate CSR, and philanthropy
- Population density: India's high population density ensures that even kiosks in rural areas have large potential local markets

Note: 1. Price figures from 2017
Source: SWE interviews, Dalberg analysis

Case study: In 2019, many of the rural villages in Maharashtra served by Naandi's kiosks were hit by severe monsoon floods

Situation Overview

- India's annual western monsoon, running from June to September, supplies much of the western and northern regions of the country with nearly all of the rainfall it will receive in an entire year
- Over the years, climate change has caused monsoons to become increasingly erratic: rainfall is less frequent, and downpours are more intense
- In June and July of 2019, much of the area comprising Naandi's operations in Western Maharashtra were hit with serious floods as the region received one of the wettest monsoons ever
- Many regions were inundated, with towns and villages flooded both due to direct rainfall and from severe riverine flooding



Water related weather events form an increasing share of natural disasters in India

Source: 1. EM-DAT database; 2. Dalberg analysis

Threats to Safe Water Supply

Severe flooding has several potentially serious impacts on safe water supply:

Quantity — If water cannot be treated or distributed due to floods, supply quantity will decrease

Continuity — Flood waters may temporarily interrupt supply continuity through direct effects (damaging equipment, polluting water supplies) and indirect effects (power cuts, distribution network disruptions)

Quality — Flood waters can severely pollute raw water sources, reducing quality

Affordability — Repeated floods can damage equipment or reduce supplies, leading to longer-term increased cost

Accessibility — Flooding limits ability of customers to reach distribution points, and distribution staff to reach customers

Case study: Naandi's community partnerships and advanced planning enabled continuous service throughout the flood

Inherent Resilience Mechanisms

Financial

- Counter-cyclical demand: As flooding worsened, Naandi's revenues increased because customers sought safe, reliable supply to avoid water-borne illness

Operational

- Community Partnerships: Naandi selects and operates rural sites in partnership with Gram Panchayats (local governments), enabling higher trust and integration into local villages
- Flood-resistant site selection: To counteract potential monsoon flooding, Naandi had located kiosks only at flood-resistant locations

Adaptive Resilience Mechanisms

Financial

- None: Because of it's high intrinsic resilience capabilities, Naandi did not need to employ any adaptive financial resilience mechanisms

Operational

- Staff overtime: Existing kiosk staff worked significantly longer hours to satisfy increased demand

Outcomes

- **Continuous water supply**: Naandi's customers were able to access safe, affordable drinking water throughout the flood, even as other sources were contaminated or forced offline
- **Temporarily increased sales:** During the flood, average per-kiosk sales increased as customers sought out trusted suppliers to avoid water-borne illness
- **Permanently Larger Customer Base:** After the flood, customers who had used Naandi's services on an emergency basis returned to the kiosk as regular purchasers
- **Improved Brand Recognition**: Because of their community presence during and after the floods, Naandi's brand recognition improved with the local community

Key Water Outcomes

Quantity: Customer demand increased due to failure of alternative resources

Continuity: No change due to continuous service

Quality: No change

Affordability: No change because no damage

Accessibility: Minimal impact because of high population density in local villages facilitated access

Case study: Lessons for other SWEs

1 Flood-proof infrastructure

Planning in advance for extreme events is a foundation for larger success

- Given the seasonal nature of the monsoonal threat, Naandi ensured that all of their sites were selected and prepared considering the possibility of floods
- This advanced planning cost little and served as the baseline for Naandi's overall response; without selecting resilient sites, their operations would have been forced to shut entirely

2 Retain spare capacity

Keeping available spare capacity can enable SWEs to meet peak demand at critical moments for consumers

- As the floods worsened, demand for Naandi's services grew significantly.
- In their climate response role as an essential service provider, SWEs should be prepared to meet excess demand in crisis circumstances so that communities can be assured of a continuous supply of safe drinking water.

3 The importance of community trust

Community trust and partnerships can enhance the impact of other resilience preparations

- Naandi selects and maintains sites in partnership with local leaders and institutions
- When local communities were unsure about the quality of drinking water, they were able to trust Naandi as a reliable source because of these social ties

Source: SWE interviews; Dalberg analysis

Case study: Water4 operates "mini-grid" systems that pipe water from village treatment points to distribution nodes, homes, and businesses

Water4

Company Information

Case Study Location:
Organization-wide

Water Filtration Method:
Sediment/Micro-sediment + UV + Chlorination

Climate Segment:
Multiple

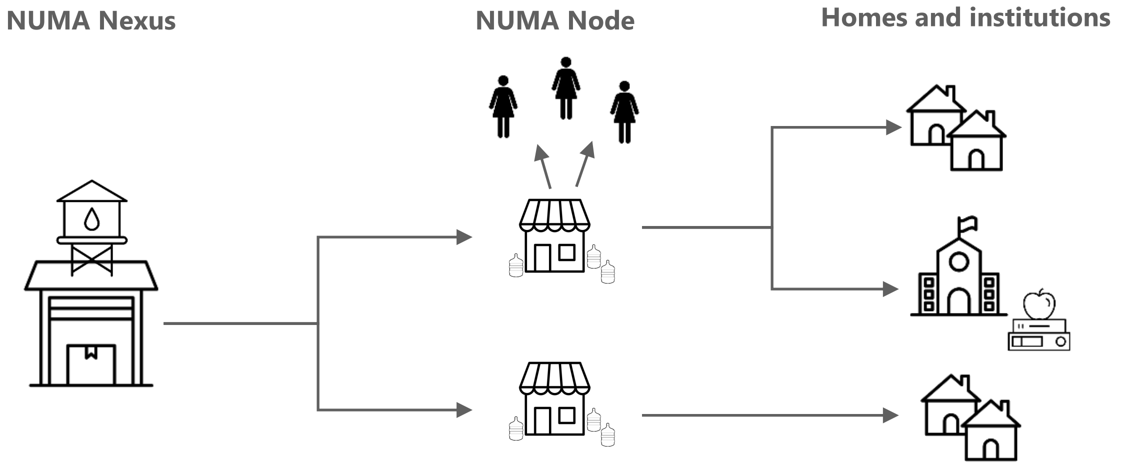
Operational in Burkina Faso, Burundi, DRC, Ethiopia, Ghana, Kenya, Liberia, Malawi, Rwanda, Sierra Leone, Tanzania, Togo, Uganda, Zambia, and Peru

~110 water systems operational

~$.04 / 20L pickup
~$.045 / 20L piped

Business Model

- Distribution model: Water is extracted from wells and refined at a central location ("Nexus") and then transmitted by pipes to additional distribution-only points ("Nodes") and to home consumers.
- Pricing model: For household/institutional connections, consumers pay a one-time connection fee, and then can consume water on a metered connection at a moderate (12.5%) cost vis-à-vis pickup prices.
- Geographical focus: Water4 primarily serves rural villages; each system can serve up to ~3000 consumers



1 *Water is extracted from bore wells and treated at a central Nexus site within the village. Nexus sites maintain an elevated storage tank to provide constant water pressure.*

2 *Water is piped up to 1 km to substations ("nodes"), which act as retail stores for pickup sales.*

3 *Water is also delivered from nodes to individual homes and businesses which pay for an on-site connection.*

Source: 1. SWE data, SWE interviews

Case study: This distinct service delivery model offers Water4's operations unique resilience tactics

Inherent Resilience Mechanisms

Financial

- Capital reserves: Water4 maintains a portion of revenues in escrow for capital maintenance expenditures

Operational

- Localized service delivery: By delivering services closer to consumers places of residence, Water4 is able to mitigate disruptions to customers during floods and storms
- 25000 litre reserves: Water4 maintains sizeable potable water reserves to ensure constant pressure which can also serve as climate-resistant water stores

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Adaptive Resilience Mechanisms

Financial

- Price adjustments: Water4 can make temporary price adjustments to discourage wastage (i.e., high home consumption) in droughts

Operational

- Relocation: NUMA systems are modular systems which can be relocated for a relatively small cost
- Adaptable solar pumps: Water4's pumping systems employ solar energy and can be adjusted to match aquifer yields in low yield applications

Outcomes

- **Continuous water supply**: Water4's customers have access to a system which provides constant pressure for 24 hour water access, even in adverse conditions, without relying on high volumes of water supply.
- **Accessible consumption in emergencies:** By virtue of its localized distribution model, access during climate-induced emergencies is simpler for consumers.
- **Flexible supply parameters:** Water4 can adjust supply through multiple means—including adjustable extraction rates, potable water storage, and price measures—to ensure customers' essential needs are met.

Key Water Outcomes

- **Quantity**: Robust backup systems to ensure no change
- **Continuity**: No change due to resilient architecture
- **Quality**: No change
- **Affordability**: Small potential increase in climate emergencies to limit demand
- **Accessibility**: Accessibility remains high because of localized service delivery

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The world was segmented into 7 ‘climate resilience’ segments, based on their climate risk and resilience profile

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Water climate risk: Used current water climate risk and expected climate change impact as indicators to determine the water climate risk categories

a

Current water climate risk

Extent of climate change impact on current water resources (quality, quantity risk etc.) where SWEs are located is an important measure of how vulnerable their business is to climate shocks/stresses

b

Expected climate change impact

Expected change in climate change impact (by 2030) on water resources and its magnitude can help inform SWEs' mitigation strategies as well as expansions plans

Source: Countries with low data availability excluded from final segments

Water climate risk

Used river basin level indicator scores to determine a water climate risk score for each basin

Indicator score

River basin

Current water risk

- Composite score based on the extent of risk water resources faced due to climate change. This is based on multiple sub-indicators
  - Water quality risk
  - Water quantity risk
  - Reputation and regulatory risk
- Each basin is assigned a score on these sub-indicators based on their corresponding risk levels (water quantity risk assesses current baseline water stress levels, drought and flood occurrence, seasonal variability etc.)
- Combining the sub-indicator scores, each basin is assigned a score of 0-5, where 0 indicates very low risk and 5 indicated a very high risk; scores were normalized to a scale of 0-1

Expected climate change impact (by 2030)

- Composite score based on the projected effects of climate change on water resources. This is based on two sub-indicators
  - Change in water stress by 2030 (BAU scenario)
  - Change in seasonal variability by 2030 (BAU scenario)
- Each basin is assigned a sub-indicator score based on the magnitude of expected change from baseline indicator value (i.e., '1.5x expected increase in water stress' is assigned a '0.5' score)
  - Water stress: Near normal change or any projected decrease marked as '0'; >2x projected increase marked as '1'
  - Seasonal variability: Near normal change marked as '0'; direction of change not considered (i.e., both '1.25x decrease' and '1.25x increase' assigned a '0.25' score)
- Combining the sub-indicator scores (simple average), each basin is assigned a score of 0-1, where 0 indicates negligible climate change impact expected and 1 indicates a very high projected impact

Composite score

- Composite score calculated by averaging the two indicator scores (equal weightage given to both indicators)
- Each river basin is assigned a category based on statistical distribution (percentiles) of the composite scores – very low, low, medium, high

Very low risk | Low | Medium | High risk

2

Resilience enablers: Used social, financial and institutional resilience as indicators to determine resilience categories

a

Financial Ecosystem

The availability of finance in a region will enable SWEs to fund investment in climate preparations and to more effectively respond or repair after climate-induced shocks to business operations.

b

Market Vibrancy

Demand-side elements of the SWE's operating region influence an SWE's capacity to generate funds for climate investments through sales and to continue operations in the event of a crisis.

3

Institutional Support

Legal-institutional elements of an SWE's operating environment will contribute to SWE resilience by determining the efficiency of the local business environment and the regulatory attitude towards climate adaptation.

Source: Analysis carried out for ~80 low income/lower middle income countries only; a 'very high' resilience score assumed for all upper middle income/high income countries; countries with low data availability excluded from final segments

Resilience enablers: Financial ecosystem

Combined country and state/sub-region level indicator scores to determine a financial resilience score for each basin

Indicator score

Country

Net ODA inflows/capita ($PPP)
- Determined net ODA received per capita
- Each country assigned a score based on statistical distribution (percentiles) - 1 (low); 2 (medium); 3 (high)

Country credit rating
- Determined country level credit ratings
- Each country assigned a score based on their rating - lower than BBB- assigned '1' (low); higher than BBB- assigned '3' (high)

Fixed capital formation/capita ($PPP)
- Calculated by dividing gross fixed capital formation by total population
- Each country assigned a score based on statistical distribution (percentiles) - 1 (low); 2 (medium); 3 (high)

- Calculated separate scores for external financing (average of ODA inflows/capita and country credit rating score) and domestic financing availability (fixed capital formation/capita score)
- Composite score calculated by averaging these two sub-indicator scores (equal weightage given to both indicators)

River basin

- For top 9 countries by population*
    - Adjusted financial resilience score for each sub-region/state using sub-national ease of doing business ranking
- For other countries
    - Used the country level financial resilience score

Composite score

- Each basin is assigned a category based on statistical distribution (percentiles) of the composite scores – low, medium, high

High | Medium | Low

Source: *Data available for only 7 out of the 9 countries; average indicator score considered wherever data was not available; Analysis carried out for ~80 low income and lower middle income countries

2 b

Resilience enablers: Market vibrancy

Combined country and state/sub-region level indicator scores to determine a social resilience score for each basin

Indicator score

Country

Urban population density (ppl/sq km)

- Calculated by dividing total urban population by total urban area

Rural population density (ppl/sq km)

- Calculated by dividing total rural population divided by total rural area

Ability to pay (% population)

- Cost to serve (CTS): Determined SWE avg. cost to serve per month per person ($PPP)
- Ability to pay (ATP): Calculated avg. monthly income used for drinking water per person ($PPP)

River basin

- For the top 9 countries by population
  - Each river basin scored based on the global population density heat map - 1 (low); 2 (medium); 3 (high)
- For other countries
  - Country's population distributed across river basins based on their relative land area
  - Assumed country level urban/rural population and land ratio to determine urban/rural population density for each basin
  - Each river basin assigned a score based on statistical distribution (percentiles) - 1 (low); 2 (medium); 3 (high)

- CTS: Assumed country level cost to serve
- ATP: For the top 9 countries by population*, determined per capita monthly income for each sub-region/state (by applying the country level GNI/ expenditure ratio to state/sub-region level GNI); for other countries, assumed country level ATP
- Determined % of population unable to afford SWE product (ATP>cost)
- Each basin is assigned a score based on this % - 0% assigned '3' (high); <10% assigned '2' (medium)'; >20% assigned '1' (low)

Composite score

- Composite score calculated by averaging the three indicator scores (equal weightage given to all indicators)
- Each river basin is assigned a category based on statistical distribution (percentiles) of the composite scores – low, medium, high

High | Medium | Low

Source: *Data available for only 7 out of the 9 countries; average indicator score considered wherever data was not available; Analysis carried out for ~80 low income and lower middle income countries

2 c

Resilience enablers: Institutional support

Combined country and state/sub-region level indicator scores to determine an institutional resilience score for each basin

		Ease of doing business	Sustainable policies/institutions
Indicator score	Country	• Determined ease of doing business score for each country on a scale of 0 to 100, where 0 represents the lowest and 100 represents the best performance • Each country assigned a score based on statistical distribution (percentiles) - 1 (low); 2 (medium); 3 (high)	• Determined the extent of policies/institutions fostering the protection and management of natural resources and climate change on a scale of 1 to 6, where 1 represents the lowest and 6 represents the best performance[1] • Each country assigned a score based on statistical distribution (percentiles) - 1 (low); 2 (medium); 3 (high)

	River basin	• For top 9 countries by population* –
		  • Adjusted ease of doing business indicator score for each sub-region/state using sub-national ease of doing business ranking
		• For other countries
		  • Used the country level ease of doing business score
			• Used the country level sustainable policies/institutions score

Composite score		• Composite score calculated by averaging the two indicator scores (equal weightage given to both indicators) • Each river basin is assigned a category based on statistical distribution (percentiles) of the composite scores – low, medium, high	

High | Medium | Low

Notes: *Data available for only 7 out of the 9 countries; [1]For 5 countries, used the CCP index (climate policy index) instead, where the scale of score (0-100) was normalized to a 6 point scale for comparison; average indicator score considered wherever data was not available; analysis carried out for ~80 low income and lower middle income countries

2

Resilience enablers: Resilience categories assigned to basins based on their performance on the three key criteria; involved qualitative and quantitative assessment

Institutional support	Financial ecosystem	Market vibrancy	Resilience categories
H	H	H	Well rounded
M	H	H	Well rounded
L	H	H	Well rounded
H	M	H	Well rounded
M	M	H	Demand-led
L	M	H	Demand-led
H	L	H	Demand-led
M	L	H	Demand-led
L	L	H	Vulnerable
H	H	M	Well rounded
M	H	M	Financing led
L	H	M	Financing led
H	M	M	Moderate
M	M	M	Moderate
L	M	M	Moderate
H	L	M	Moderate
M	L	M	Vulnerable
L	L	M	Vulnerable
H	H	L	Financing led
M	H	L	Financing led
L	H	L	Vulnerable
H	M	L	Moderate
M	M	L	Vulnerable
L	M	L	Vulnerable
H	L	L	Vulnerable
M	L	L	Vulnerable
L	L	L	Vulnerable

Resilience category classification

- Resilience indicator score for each river basin finalized after a round of qualitative assessment using external inputs (experts, clients etc.)
- For low income/lower middle income countries, each river basin is assigned a resilience category based on their performance on the three key resilience indicators (i.e. financial, social and institutional resilience) as per the LHS matrix
- For upper middle income/high income countries, each river basin is assumed to be highly resilient and is hence assigned the 'comprehensive' resilience category

A combination of quantitative and qualitative assessment used to determine the final resilience category for each river basin

3

Finally, the world is divided into key 'climate resilience segments' by combining the risk and resilience categories

Focus of study[1]

Climate resilience segment	Climate Water Risk	Resilience enablers	Definition
• *Moderate/high risk,* **vulnerable**			Most vulnerable regions - medium to high risk of climate change and very little capacity for resilience
• *Moderate/high risk,* **financing-led resilience**			While climate risk is high, water systems in these regions are able to access domestic and/or intl. financing to build resilience. Due to low density and/or income levels, they cannot depend on strong demand when under duress
• *Moderate/high risk,* **demand-led resilience**			While climate risk is high and financing options and institutional support is low, these regions are dense and have high income households; this robust demand likely to be a buffer during climate stress
• *High risk,* **moderate resilience**			Moderate level of resources available to respond to the significant climate change impact expected
• *Moderate risk,* **moderate resilience**			Moderate level of resources available to respond to the medium climate change impact expected
• *High risk,* **well-rounded**			Despite high climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt
• *Moderate risk.* **well-rounded**			Despite moderate climate risk, these regions have sufficient access to financing, robust service demand, favourable policies and business climate to adapt
• *Low/very low climate risk*			Regions where water levels are high and climate change is unlikely to affect seasonal variation or water stress
• **Comprehensive**			Regions that are well placed to respond to any magnitude of climate change, driven by a robust social and financial ecosystem

Note: 1. The final two segments (8 and 9) are at very low risk and/or have high resilience (typically in wealthy countries). We have excluded them from more detailed analysis in this study as their resilience levels are already high. 2. Total underserved segment not currently receiving water from safe sources.

Sources

Indicator	Source
Water climate risk	Global maps 2.1, “Water risk atlas”, World Resources Institute (WRI) (2015)
Water climate risk	Global maps 2.1, “Aqueduct Water Stress projections”, World Resources Institute (WRI) (2015)
Resilience: Financial ecosystem	“Net ODA per capita ”, World bank (2018)
Resilience: Financial ecosystem	“Price level ratio of PPP conversion factor (GDP) to market exchange rate”, World Bank (2018)
Resilience: Financial ecosystem	“Country credit ratings”, Wikirating (S&P, Moody’s, Fitch) (2019)
Resilience: Financial ecosystem	“Gross fixed capital formation”, World Bank (2018)
Resilience: Financial ecosystem	“Sub-National ease of doing business ranking”, World Bank, IBRD/IDA (2012-2018)
Resilience: Market vibrancy	“Annual per capita consumption data”, World bank (2010)
Resilience: Market vibrancy	“Gross national income/capita”, World Bank (2018)
Resilience: Market vibrancy	“Subnational Gross national income/capita”, UNDP (2018)
Resilience: Market vibrancy	“GDP per capita growth (2010-2018)”, World bank (2018)
Resilience: Market vibrancy	Dalberg Advisors, “SWE Market Survey” (2017)
Resilience: Market vibrancy	“Gridded global population density”, Socioeconomic Data and Applications Center (SEDAC), NASA (2015)
Resilience: Market vibrancy	“Urban population”, “Rural population”, “Total population”, World bank (2018)
Resilience: Market vibrancy	“Urban land area”, “Rural land area”, “Total land area”, World bank (2018)
Resilience: Market vibrancy	“Income share by population deciles”, World bank (2010-2017)
Resilience: Market vibrancy	% income used on safe drinking water (3%), OECD guidelines
Resilience: Institutional support	“Climate change performance Index”, Germanwatch (2019)
Resilience: Institutional support	“CPIA policy and institutions for environmental sustainability rating”, World bank development indicators (2018)
Resilience: Institutional support	“National and sub-national ease of doing business ranking”, World bank development indicators (2020)